Post-Harvest Handling Protocol for Fruits & Vegetables

Contents

1.0 Background:

Ministry of Agriculture & Farmers' Welfare, Government of India has launched a Central Sector Scheme for formation and promotion of 10,000 Farmer Producer Organizations (FPOs) with following objectives:

- To provide holistic and broad-based supportive ecosystem to form new 10,000 FPOs to facilitate development of vibrant and sustainable income-oriented farming and for overall socio-economic development and wellbeing of agrarian communities.

- To enhance productivity through efficient, cost-effective, and sustainable resource use and realize higher returns through better liquidity and market linkages for their produce and become sustainable through collective action.

- To provide handholding and support to new FPOs up to 5 years from the year of creation in all aspects of management of FPO, inputs, production, processing and value addition, market linkages, credit linkages and use of technology etc.

- To provide effective capacity building to FPOs to develop agriculture entrepreneurship skills to become economically viable and self-sustaining beyond the period of support from government.

1.1 Farmer producer Organization (FPO):

FPO is a generic name, which means and includes farmer- producers' organization incorporated/ registered either under Part IXA of Companies Act or under Co-operative Societies Act of the concerned States and formed for the purpose of leveraging collectives through economies of scale in production and marketing of agricultural and allied sector. However, FPOs registered under Cooperative Societies Act of the State (including Mutually Aided or Self-reliant Cooperative Societies Act by whatever name it is called) for the purpose of this Scheme, is to be insulated from all kinds of interference including in election process and day to day management through suitable provisioning in their Memorandum of Association and Byelaws with a view to encourage healthy growth and development of FPO.

1.2 Broad Services and Activities to be undertaken by FPOs:

The FPOs may provide and undertake following relevant major services and activities for their development as may be necessary: -

i. Supply quality production inputs like seed, fertilizer, pesticides, and such other inputs at reasonably lower wholesale rates.

ii. Make available need-based production and post-production machinery and equipment like cultivator, tiller, sprinkler set, combine harvester and such other machinery and equipment on custom hiring basis for members to reduce the per unit production cost.

iii. Make available value addition like cleaning, assaying, sorting, grading, packing as well as farm level processing facilities at user charge basis on reasonable rates. Storage and transportation facilities may also be made available.

iv. Undertake additional income generating activities like seed production, bee keeping, mushroom cultivation etc.

v. Undertake aggregation of smaller lots of farmer-members' produce; add value to make them more marketable.

vi. Facilitate market information/intelligence about the produce for judicious decision in production and marketing.

vii. Facilitate logistics services such as storage, transportation, loading/un-loading etc. on shared cost basis.

viii. Market the aggregated/value added produce with better negotiation strength to the buyers and in the marketing, channels offering better and remunerative prices.

This tool kit on handling protocol is an attempt to provide the simple and clear guidelines to the FPOs formed under the central sector scheme and engaged in growing and marketing of fresh fruit and vegetables with respect to practices to be adopted in pre- and post-harvest handling of fresh produce to ensure growing high quality of produce and preserve its quality and freshness after harvesting till the time it reaches to the buyer.

1.3 General principles of Post-harvest management

- Fruits and Vegetables are the living entities and continue breathing even after harvest
- Due to continuous respiration and metabolism Fruits and Vegetables follow the typical life cycle similar to living organisms i.e., grow on parent plant, harvested at mature stage, start aging immediately after harvesting and finally perish, if not consumed before becoming unfit for consumption.
- After plucking of Fruits and vegetables, it starts consuming the food stored within to meet the energy requirements for breathing and metabolism which results in their deterioration over a period.
- The rate of respiration of Fruits and Vegetables varies from one to another and is influenced by several internal and external factors, such as genetic composition (Variety), stage of harvest, surrounding temperature, relative Humidity etc.
- Continuous respiration and metabolism after harvesting leads to a number of changes in the fruits and vegetables such as change in appearance, texture, color, taste, flavor and loss of water in the form of water vapors.
- If fruits and vegetables are not handled meticulously after harvesting, such changes lead to an unacceptable level and rejection by the buyer/consumers.
- Thus, post-harvest handling and management of fresh fruits and vegetables is of utmost important to avoid food loses due to decay and spoilage and to increase the shelf life of the produce.

1.4 Causes of post-harvest losses

Horticultural crops not only provide nutritional and healthy foods to human beings, but also generate a considerable cash income for growers. However, horticultural crops typically have high moisture content, tender texture, and high perishability. If not handled properly, a high-value nutritious product can deteriorate and rot in a matter of days or hours. The causes of post-harvest losses can be divided into different categories:

- Metabolic: All fresh horticultural crops are live organs. The natural process of respiration involves the breakdown of food reserves and the aging of these organs.

- Mechanical: Owing to their tender texture and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury. Poor handling, unsuitable containers, improper packaging, and transportation can easily cause bruising, cutting, breaking, impact wounding and other forms of injury.

- Developmental: These include sprouting, rooting, seed germination, which lead to deterioration in quality and nutritional value.

- Parasitic diseases: High post-harvest losses are caused by the invasion of fungi, bacteria, insects, and other organisms. Micro-organisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defense mechanism and has plenty of nutrients and moisture to support microbial growth.

- Physiological deterioration: Fruits and vegetable cells are still alive after harvest and continue their physiological activity. Physiological disorders may occur due to mineral deficiency, low or high temperature injury or undesirable atmospheric conditions, such as high humidity, physiological deterioration can also occur spontaneously by enzymatic action leading to over-ripeness and senescence, a simple aging phenomenon.

- Lack of market demand: Poor planning pr inaccurate production and market information may lead to over production of certain fruits or vegetables which can't be sold in time. This situation occurs most frequently in areas where transportation and storage facilities are inadequate. Produce may lie rotting in production areas, if farmers are unable to transport it to people who need it in distant locations.

- Consumption: These losses can be due to inadequate preservation methods at home, methods of cooking and preparation such as peeling, consumption styles etc.

- Others
    - Lack of clear concept of packing house operations.
    - Lack of awareness among the growers, contractors and even the policy makers.
    - Lack of infrastructure.
    - Late realization of its importance,
    - Inadequate technical support.
    - Wide gap in technologies available and in vogue.
    - Inadequate post-harvest quality control.
    - Unorganized marketing.
    - Absence of pre-cooling and cold storage.
    - Inadequate market facilities, market intelligence and market information service (MIS)
    - Poor storage facilities.

Group	Examples	Principal causes of postharvest losses and poor quality (in order of importance)
Root vegetables	Carrots	Mechanical injuries
	Beets	Improper curing
	Onions	Sprouting and rooting
	Garlic	Water loss (shriveling)
	Potato	Decay
	Sweet Potato	Chilling injury (subtropical and tropical root crops)
Leafy vegetables	Lettuce	Water loss (wilting)
	Chard	Loss of green color (yellowing)
	Spinach	Mechanical injuries
	Cabbage	Relatively high respiration rates
	Green onions	Decay
Flower vegetables	Artichokes	Mechanical injuries
	Broccoli	Yellowing and other discolorations
	Cauliflower	Abscission of florets
		Decay
Immature-fruit vegetables	Cucumbers	Over-maturity at harvest
	Squash	Water loss (shriveling)
	Eggplant	Bruising and other mechanical injuries
	Peppers	Chilling injury
	Okra	Decay
	Snap beans	
Mature-fruit vegetables and fruits	Tomato	Bruising
	Melons	Over-ripeness and excessive softening at harvest
	Citrus	Water loss
	Bananas	Chilling injury (chilling sensitive fruits)
	Mangoes	Compositional changes
	Apples	Decay
	Grapes	
	Stone fruits	

Figure 1. Cause of Post- harvest Losses

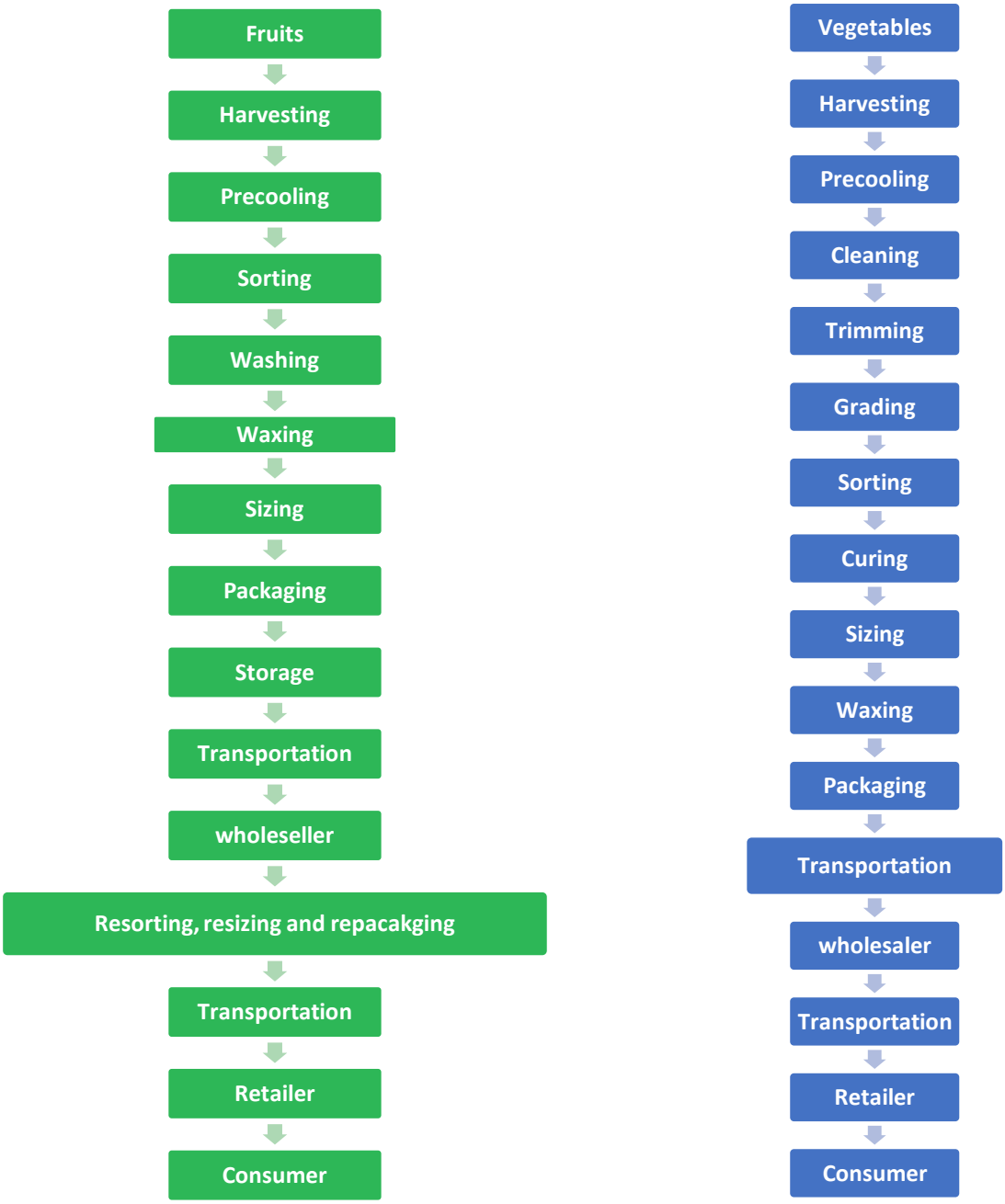
1.5 Impact of post-harvest losses

Post-harvest losses of horticultural crops affect both the nutritious status of the population and economy of the country.

- Nutrition: Fruits and vegetables are rich source of vitamins and minerals essential for human nutrition. These are wasted in transit from harvest to consumer represent a loss in the quantity of a valuable food. This is important not only in quantitative terms, but also from the point of view of quality nutrition.
- Economy: Careless harvesting and rough handling of perishable bruise and scar the skin, thus reducing quality and market price. Such damaged produce also fails to attract the international buyers and bring the exporting country less profit and bad name. This ultimately results in huge

economic losses to the country. For improving the situation, it is essential to create awareness among growers, farm workers, manager's traders, and exporters about the extent of losses being incurred and their economic consequences. These groups of people involved in the fruit industry also need to learn the basic principles of fruit handling and storage. In addition, the government needs to provide basic infra-structure like storage, handling, grading, packing, transport and marketing facilities and technical expertise. This could be carried out by the public and private sectors.

2.0 Flow Chart for Post-Harvest Handling of Fruits and Vegetables



3.0 Harvesting Method

There are two methods of harvesting. They are (a) Hand harvesting and (b) Mechanical harvesting. Several factors are considered in deciding on the appropriate method of harvesting a crop. Some crops offer no choice since machines have not yet been developed for harvesting them. In other cases, the product is so delicate that mechanical harvesting becomes a great challenge and is not cost effective. Where human labor is plentiful and inexpensive, hand picking may be economical.

(a). Hand Harvesting: Harvesting by hand is being practiced in all the horticultural crops since time immemorial. Some of the crops e.g., flowers even today are harvested by hands. But in India hand harvesting is still the most common method used in horticultural commodities. Due to inadequate mechanization, small land holdings and diversity of crops being grown by a small farmer. In developing countries, most produce for internal rural and urban markets is harvested by hand. It predominates for the fresh market and extended harvest period (due to climate, there is accelerated ripening and a need to harvest the crop quickly) particularly the produce which is more susceptible to physical injury and soft fruit like grapes/litchis/jamun, and strawberry and others berries which are borne on low growing plants.

Figure 2. Hand Harvesting

(i). Benefits of Hand Harvesting

- Hand harvesting is usual where fruit or other produce is at various stages of maturity within the crop, that is, where there is need for repeated visits to harvest the crop over a period of time.
- Accurate selection of maturity. The result is a higher quality product with minimum damage. Examples Breaking off - twisting off pineapple, papaya, tomato Cutting - snipping off mandarins and table grapes with secateurs and apple, roses etc.
- Accurate grading (discarding the damaged, diseased fruits at the time of harvesting only).
- Less expensive

- Minimum damage to the commodity
- Rate of harvesting can be increased by employing more number of persons
- Minimum of capital investment
- Some labour can be used for harvesting different types of crops eg. apple and gladiolus can be harvested by same person but cannot be harvested by same machine.
- Immature or small sized fruits could be left on the plant for next harvest eg.pea, capsicum where 3-4 harvests are taken from the same plant.

(ii). Disadvantages of hand harvesting

- More time consuming
- Dependent on availability of labour. Strike of labour during the time of harvesting may result in crop losses.
- Harvesting small fruits and from thorny plants are major obstacle.

(b). Mechanical harvesting: In region where labour cost is high machine harvest is popular for processing crops because it could damage the produce and subsequent faster deterioration. machine harvest is used for robust, low-unit-value ground crop such as potatoes and onions. The main advantages of mechanized harvesting are speed and the reduced costs per ton harvested. However, because of the risk of mechanical damage, it can only be used on crops that require a single harvest.

Figure 3. Mechanical harvesting

(i). Mechanical assistance: These are the simple machine used to provide assistance to hand pickers with ladder and positioners (tree towers and platforms). Combination of these processes is possible by process by providing bins mounted on trailers moving along the plant rows. 'Flying foxes' (overhead ropeways) are similar systems provided to convey heavy banana bunches into packing house.

(ii). Harvesting machine: it employs direct harvest by contact methods such as

- Shaking machine
- Picking pole fitted with cutter device - For fruits high on trees like mango, avocados.
- The 'shake and catch' machine used in apple and citrus to harvest and collect the fruit by shaking the trunk and collection the fallen fruit on the canvas which spread under the tree.
- Use of vibrating digger is used harvest underground roots/tuber/rhizomes.
- Use of robotics to harvest mushroom by method of sucker end-effecter.

Figure 4. Coffee Mechanical Harvester

Figure 5. Potato Harvester

Figure 6. Carrot Harvester

Figure 7. Sweet potato harvester

Figure 8. Harvesting lettuce at field

4.0 Post-harvest Handling

Being living organs, fruits and vegetables continue to respire even after harvesting when they have a limited source of food reserves. In addition to degradation of respiratory substrates, a number of changes in taste, color, flavour, texture, and appearance take place in the harvested commodities which make them unacceptable for consumption by the consumers if these are not handled properly. Post-harvest technology starts immediately after the harvest of fruits and vegetables. The whole process of processing the commodities is categorized as Handling of fresh produce.

Post-harvest Technology of fresh fruits and vegetables combines the biological and environmental factors in the process of value addition of a commodity. Postharvest handling is the stage of crop production immediately following harvest, including cooling, cleaning, sorting, and packing. The instant a crop is removed from the ground, or separated from its parent plant, it begins to deteriorate. Post-harvest treatment largely determines final quality, whether a crop is sold for fresh consumption, or used as an ingredient in a processed food product.

The most important goals of post-harvest handling are keeping the product cool, to avoid moisture loss and slow down undesirable chemical changes, and avoiding physical damage such as bruising, to delay spoilage. Sanitation is also an important factor, to reduce the possibility of pathogens that could be carried by fresh produce, for example, as residue from contaminated washing water. After the field, post-harvest processing is usually continued in a packing house. This can be a simple shed, providing shade and running water, or a large-scale, sophisticated, mechanized facility, with conveyor belts, automated sorting and packing stations, walk-in coolers, and the like. In mechanized harvesting, processing may also begin as part of the actual harvest process, with initial cleaning and sorting performed by the harvesting machinery. Initial post-harvest storage conditions are critical to maintaining quality. Each crop has an optimum range for storage temperature and humidity. Also, certain crops cannot be effectively stored together, as unwanted chemical interactions can result.

Various methods of high-speed cooling, and sophisticated refrigerated and atmosphere-controlled environments, are employed to prolong freshness, particularly in large-scale operations. Regardless of the scale of harvest, from domestic garden to industrialized farm, the basic principles of post-harvest handling for most crops are the same: handle with care to avoid damage (cutting, crushing, bruising), cool immediately and maintain in cool conditions, and cull (remove damaged items). Once harvested, vegetable and fruit are subject to an active process of decay. Numerous biochemical processes (postharvest physiology) are continuously changing the original composition of the crop until it becomes no longer marketable. The period before drastic change has occurred is defined as the time of "post-harvest freshness". since freshness is an important factor in product quality, its evaluation should rest upon objective methods, but until recently only sensory tests or mechanical and colorimetric, (optical) criteria have been used.

4.1. Precooling: Precooling (prompt cooling after harvest) is important for most of the fruits and vegetables because they may deteriorate as much in 1 hr at 32°C. In addition to removal of field heat from commodities, precooling also reduces bruise damage from vibration during transit. Cooling requirement for a crop vary with the air temperature during harvesting, stage of maturity and nature of crop. There are many methods of precooling viz, cold air (room cooling, forced air cooling), cold water (hydrocooling), direct contact with ice (contact icing), evaporation of water

from the produce (evaporative cooling, vacuum cooling) and combination of vacuum and hydrocooling (hydrovac cooling). Some chemicals (nutrients/growth regulators/ fungicides) can also be mixed with the water used in hydrocooling to prolong the shelf life by improving nutrient status of crop and preventing the spread of post-harvest diseases. Pre-cooling is the key component in the preservation of quality for perishable fresh produce in post-harvest systems. It is likely the most important of all the operations used in the maintenance of desirable, fresh and salable produce. Precooling is defined as the removal of field heat from freshly harvested produce in order to slow down metabolism and reduce deterioration prior to transport or storage. One of the most important factors affecting the postharvest life and quality of fruits and vegetables is temperature. Quality loss after harvest occurs as a result of physiological and biological processes, the rates of which are influenced primarily by product temperature. As the maintenance of market quality is of vital importance to the success of the horticultural industry, it is necessary not only to cool the product but to cool it as quickly as possible after harvest.

Proper pre-cooling preserves product quality by

- inhibiting the growth of decay producing microorganisms
- restricting enzymatic and respiratory activity
- inhibiting water loss
- reducing ethylene production

Importance of Precooling

(i) Importance of lag time between harvest and cooling: Field heat can cause rapid deterioration of some horticultural crops and therefore it is desirable to remove this heat as quickly as possible after harvesting. When it comes to produce quality, every minute counts and that precooling is among the most cost-effective and efficient quality preservation methods available to commercial crop produces. For example, strawberries experience increasing deterioration losses as delays between harvesting and cooling exceeds 1 h and the effects of the delay on cooling of strawberries is shown in Fig.9.

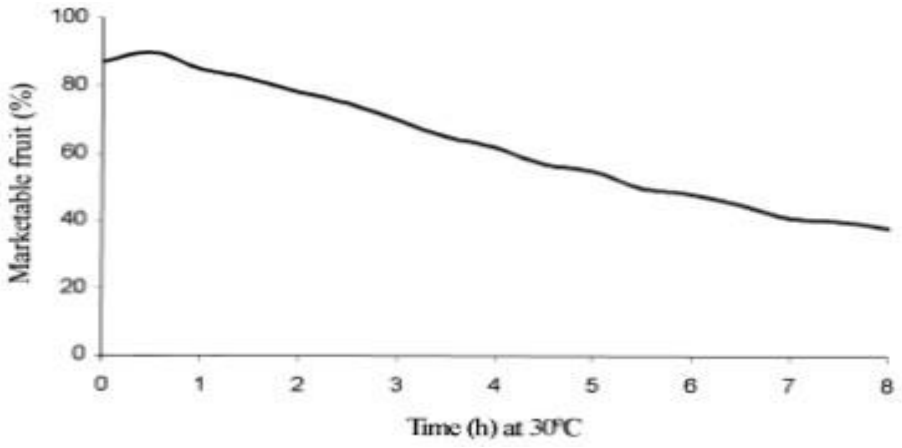


Figure 9. Effects of the delay on cooling of strawberries

From this it can be seen that even after a short time of 2 h at 300C, only 80% of the strawberries are considered marketable fruit, which represents an apparent loss of approximately 10% by not cooling the produce immediately after picking. Furthermore, precooling slows down the deterioration and the rotting process by retarding the growth of decay organisms, and it reduces wilting since transpiration and evaporation occurs more slowly at low temperatures.

(ii) **Influence of precooling on the respiration rate:** The rate of deterioration after harvest is closely related to the respiration rate of the harvested product, therefore the reduction of respiration rate is essential to preserving market quality. Since the rate of respiration is influenced by temperature, precooling to remove the field heat before storage will reduce the respiration rate and hence deterioration will decline accordingly. For example, reduction in temperature of 9.5 Degree Celsius in grapes halved the rate of respiration and doubled their keeping quality.

(iii) **Influence on metabolism:** The increase in the rate of deterioration is related to the metabolic processes of the crop. Within the plants temperature range, the rate of deterioration increases logarithmically with increasing temperature. Metabolic rates double for each 10 degree C rise in temperature. it can be seen that the quicker the temperature is reduced the less losses that can occur. Hence, precooling is essential in order to reduce metabolic changes such as enzyme activity, and to slow the maturation of perishable produce.

(iv) **Effects of rapid cooing on ethylene:** The reduction in temperature has the added advantage of reducing the production and sensitivity of the produce to ethylene that accelerates ripening and senescence. Therefore, the faster and more promptly the field heat and hence temperature is reduced after harvest, the quicker these deteriorative processes are retarded and hence the more of the initial quality can be maintained.

Method of Precooling

There are seven principal methods of pre-cooling fresh produce:

a) Room cooling
b) Forced-air cooling
c) Hydro cooling
d) Ice cooling
e) Vacuum cooling
f) Cryogenic cooling
g) Evaporative cooling

Considerable loss in quality and shelf life can occur as a result of holding harvested produce in the field before pre-cooling. All methods require sufficient refrigeration capacity to reduce the temperature of the produce within the required time plus the ability to remove the normal heat gain in the facility.

4.1.1 Room cooling: Precooling produce in a cold-storage room or precooling room is an old well-established practice. This widely used method involves the placing of produce in boxes (wooden, fiberboard or plastic), bulk containers or various other packages into a cold room, where they are exposed to cold air. It is used for produce sensitive to free moisture or surface moisture. Because this type of cooling is slow, room cooling is only appropriate for very small amounts of produce or produce that does not deteriorate rapidly**.**

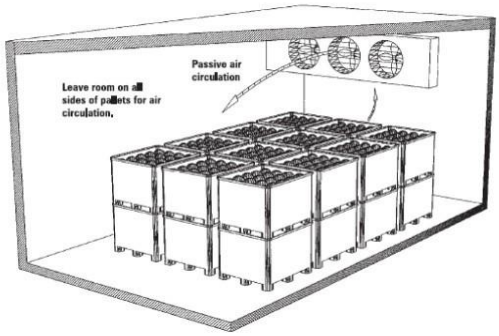


Figure 10. Room Cooling

Typically, the cold air is discharged into the room near the ceiling, and sweeps past the produce containers to return to the heat exchangers. The cooled air is generally supplied by forced or induced draft coolers, consisting of framed, closely spaced, and finned evaporator coils fitted with fans to circulate the air over the coils. Therefore, as to achieve fast and efficient cooling, care should be taken that the correct packaging (well vented) or containers and stacking patterns are used. Air velocities around the packages should be at least 60 m/min to provide the necessary turbulence to achieve heat removal and therefore attain adequate cooling. As much of the cooling is achieved by conduction, room cooling gives a slow and variable temperature reduction, therefore perishable produce used in this method must be tolerant of slow heat removal. A conventional cold store is unsuited for this operation because as much as three-quarters of the refrigerator capacity may be required simply to remove field heat and the cooling rates are frequently no better than 0.50C/h. The rooms commonly used for highly perishable fruit are designed to have an airflow rate of about 170 to 225 m3/min for a room with a capacity of 15,000 kg and sufficient refrigeration so as to cool the fruit to 5 degree C in approximately 12 h. Containers are stacked individually so that cold air from the ceiling blows over or around the produce to contact all surfaces of the containers.

Produce will dry out if a high relative humidity (90-95 percent) is not maintained. Containers should be well vented so as much air as possible can circulate through them. Spacing between the containers and walls must be from 6 to 12 inches, and between the boxes and ceiling, 18 to 24 inches. Room cooling is not recommended for bulk bins because they contain a much greater mass of produce than smaller containers. Proper design of the cooling room and refrigeration equipment is necessary for room cooling to work efficiently. The refrigeration equipment must be capable of cooling down fresh produce within 24 hours and of maintaining the storage temperature of the produce. Normally, much larger refrigeration equipment is needed to cool down the produce than to maintain the produce at a cool temperature. Room cooling has become increasingly difficult as more commodities are being handled in larger quantities and are packaged immediately after harvest due to better mechanization. These difficulties coupled with its slow and variable cooling extend the cold chain and therefore reduce the product life in subsequent storage.

4.1.2 Forced air cooling: Forced air cooling was developed to accommodate products requiring relatively rapid removal of field heat immediately after harvest. Forced air or pressure cooling is a modification of room cooling and is accomplished by exposing packages of produce to higher air pressure

on one side than on the other. This technique involves definite stacking patterns and the baffling of stacks so that the cooling air is forced through (rather than around) the individual containers. For successful forced air-cooling operations, it is required that containers with vent holes be placed in the direction of the moving air and packaging materials that would interfere with free movement of air through the containers should be minimized. A relatively small pressure difference between the two sides of the containers exists, resulting in good air movement and excellent heat transfer and hence faster cooling.

Figure 11. Forced air cooling

Produce can be cooled by a variety of different forced air-cooling arrangements. These include (a) air circulated at high velocity in refrigerated rooms, (b) by forcing air through the voids in bulk products as it moves through a cooling tunnel on continuous conveyors, and (c) by encouraging forced airflow through packed produce by the pressure differential technique. Each of these methods is used commercially, and each is suited for certain commodities when properly applied. The product cooling rate is affected by numerous variables and, therefore, the overall cost of the forced air cooling will vary. These variables include product size and shape; thermal properties; product configuration (bulk or packaged); carton vent area; depth of product load during cooling; initial product temperature; final desired product temperature and airflow rate, temperature, and relative humidity. The cooling rate in a given system depends primarily on the velocity of the cold air flowing through it, and this is the only controlling factor, since no change can be made in certain fixed factors such as size, shape, and thermal properties of the produce. In addition, the temperature of the cold air cannot be reduced below a certain safe point to avoid chilling injury. In general, the cool air necessary for this type of cooling can be generated from (a) direct expansion refrigeration system, (b) ice bank cooling system and (c) water cascade. Forced air coolers utilize centrifugal (commonly known as squirrel cage) or axial fans which push the cold air around the system. Fans are selected based on the criteria of required airflow and static pressure. These requirements are influenced by the type of produce and quantity being cooled, the arrangement of the produce (bulk, boxes or stacking) and the cooling rate required.

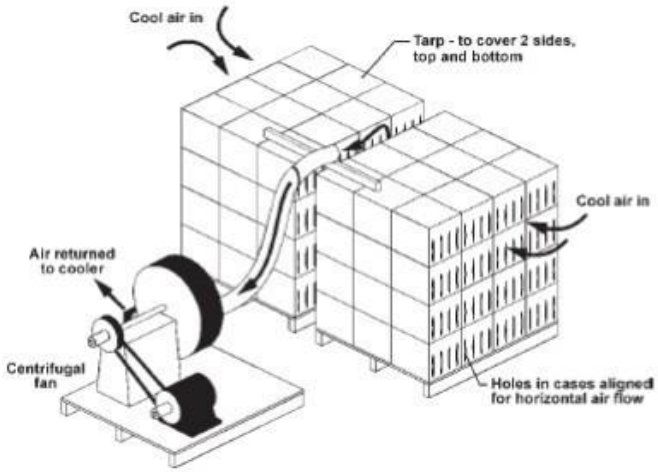


Figure.12. Forced horizontal air flow

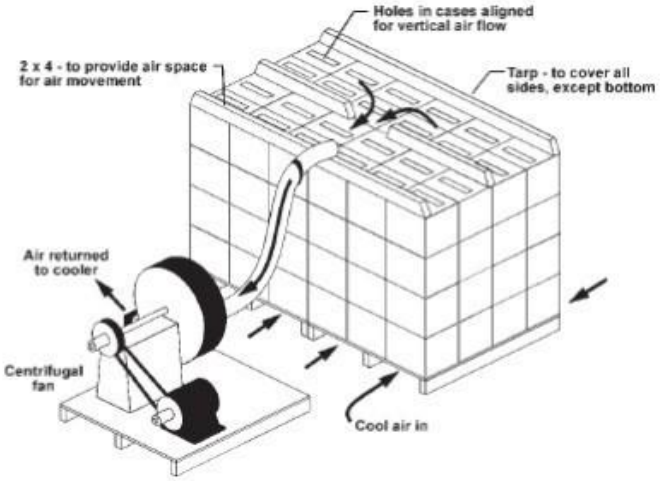


Figure.13. Forced vertical air flow

The air can be channeled to flow either horizontally or vertically. In a horizontal flow system, the air is forced to flow horizontally from one side of the pallet load to the other through holes in the sides of the pallet bin or containers. Only two sides that are opposite can be open in the pallet bin or containers. In stacking containers, the side holes must line up for the air to pass from one side of the stack to the other. In this system, the top and bottom of the pallet or containers must be sealed to prevent air from by passing the produce. In a vertical flow system, the air is forced to flow vertically from the bottom to the top of the pallet through holes in the bottom of the pallet, and containers if used, then out the top. In this system, the sides must be sealed to prevent the air from bypassing the produce. Also, if containers are used, the holes in the tops and bottoms of the containers must line up, so the air can travel vertically from one container to the next. This method is faster than room cooling because a flow of chilled air is in direct contact with the produce. In these systems, condensation on the produce can be minimized by a simple cover placed on top of the stack of containers, which prevents the entry of ambient air during handling. The key to forced-air cooling is moving the cold air through the container and its contents. Important factors in container ventilation are location of container vents, stacking of containers, and size of the vents. Container vents should be aligned whether the containers are straight-stacked or cross stacked, to maximize air flow through the containers. If vents are too small or too few, air flow is slowed. If there are too many, the container may collapse. In this method, containers are stacked close together (tight). Five percent vent-hole space per side and/or end is best. Liners, bags, wrappers, or dividers can slow the flow of air through the container, so precooling produce is usually recommended prior to additional packing. The following are forced-air cooling alternatives.

4.1.3 Cold Wall: A permanent false wall or air plenum contains an exhaust fan that draws air from the room and directs it over the cooling surface. The wall is at the same end of the cold room as the cooling

surface. The wall is built with a damper system that only opens when containers with openings are placed in front of it. The fan pulls cold room air through the container and contents, cooling the produce.

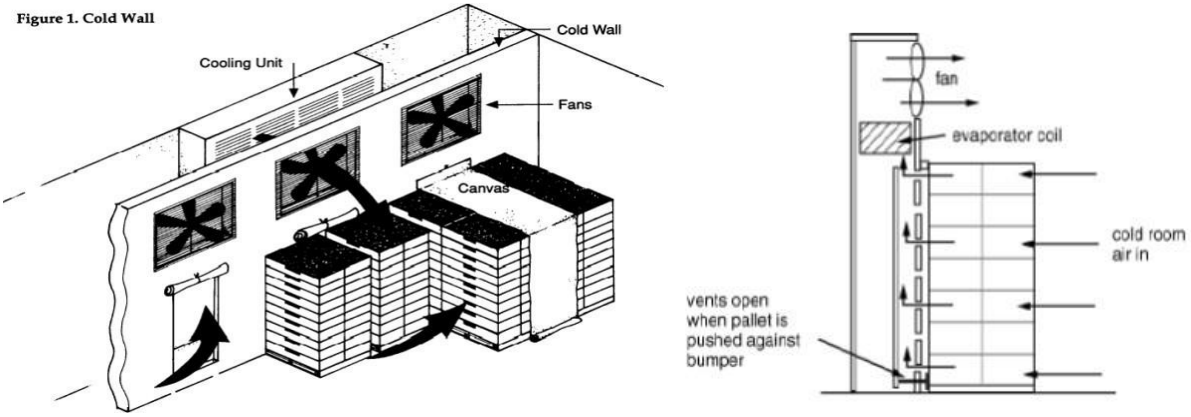


Figure. 14. Cold Wall

4.1.4 Forced-air Tunnel: An exhaust fan is placed at the end of the aisle of two rows of containers or bins on pallets. The aisle top and ends are covered with plastic or canvas, creating a tunnel. An exhaust fan draws cool room air through the container vents and top. The exhaust fan may be portable, creating a single forced-air tunnel where needed, or it may be part of a stationary wall adjacent to the cooling surface, with several fans that create several tunnels

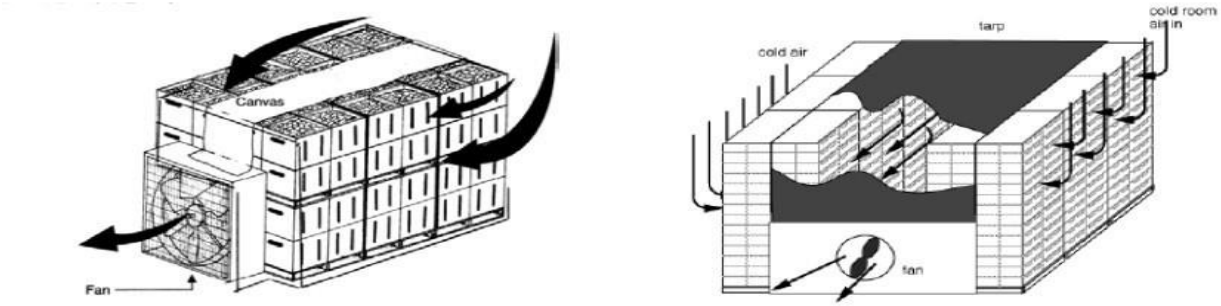


Figure 15. Forced-air Tunnel

4.1.5 Serpentine Cooling: A serpentine system is designed for bulk bin cooling. It is a modification of the cold-wall method. Bulk bins have vented bottoms with or without side ventilation. Bins are stacked several high and several deep with the forklift openings against the cold wall. Every other forklift opening—sealed with canvas—in the stack matches a cold wall opening. The alternate unsealed forklift opening allows cold air to circulate through the produce. Cold room air is drawn through the produce via the alternate unsealed openings in the stack and the top of the bin.

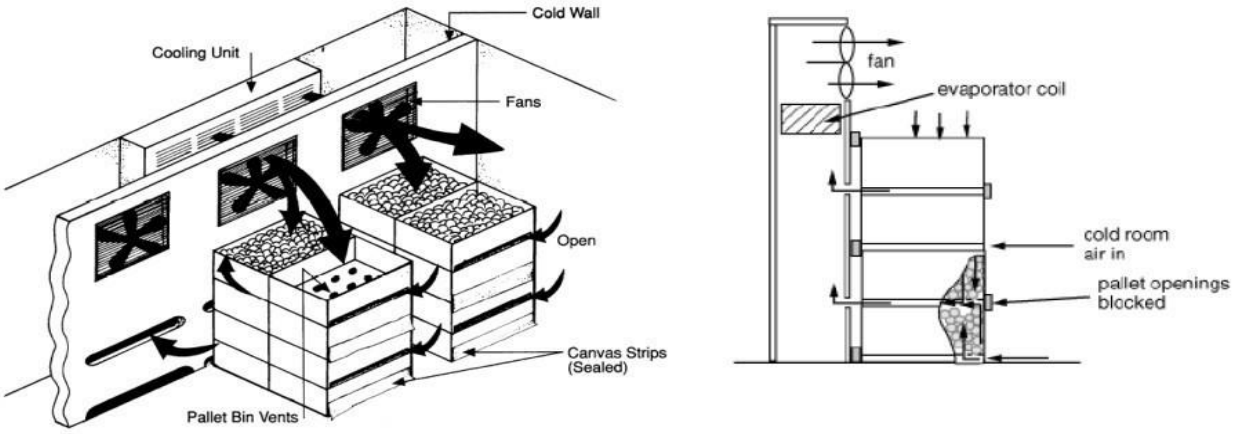


Figure 16. Serpentine Cooling

Because the cooling air comes in direct contact with the product being cooled, cooling is much faster than with conventional room cooling. Cooling by the forced air method was usually 4 to 10 times faster than room cooling but that hydrocooling and vacuum cooling was 2 to 23 times faster than forced air cooling. Another aspect of forced air cooling is that converting existing facilities is often simple and inexpensive, provided that sufficient refrigeration capacity and cooling surfaces are available. When very rapid cooling is required forced air, cooling is more costly than other precooling methods, and therefore this may limit its application to some produce which needs to be cooled extremely quickly. Another drawback of forced air cooling is that it requires a definite stacking pattern hence this technique requires skilled operators so as to achieve the required loading pattern to ensure satisfactory cooling rates.

4.1.6 Hydrocooling: Hydrocooling essentially is the utilization of chilled or cold water for lowering the temperature of a product in bulk or smaller containers before further packing. Hydrocooling is achieved by flooding, spraying, or immersing the product in/with chilled water. There are several different hydrocooler designs in operation commercially. Hydrocooling methods differ in their cooling rates and overall process efficiencies. Differences between the individual techniques are evident by the method of cooling and by the way that produce is moved or placed in the cooler. Various types of hydrocooler are available, some of which include conventional (flood) type, immersion type, and batch type. The flood type hydrocooler cools the packaged product by flooding as it is conveyed through a cooling tunnel. With the batch system, chilled water is sprayed over the product for a certain length of time, depending on the season and the incoming product temperature. These hydrocoolers have a smaller capacity than conventional hydrocoolers and are therefore less expensive. A frequent complaint about both conventional and batch type hydrocoolers is that cooling by these techniques is not uniformly and hence may leave `hot spots throughout the load. For hydrocooling to be effective, contact between the water and the product surface must be uniform. This may not be achieved by these designs of hydrocoolers as the chilled water may not be evenly distributed throughout the load, resulting in undercooling of some parts. The bulk or immersion type cooler uses a combination of immersion and flood cooling. Loose produce is immersed in cold water and remains immersed until an inclined conveyor gradually lifts the products out of the water and moves it through an overhead shower. The most rapid hydrocooling is

obtained by this cooling technique. It is nearly twice as rapid as conventional hydrocooling methods, due to the fact that moving chilled water completely surrounds the exterior surface of the produce and hence facilitates quicker temperature reduction. The bulk type cooler has the added benefit over the flood type cooler of allowing greater packaging flexibility, i.e., packaging after cooling, and therefore it may be more suitable to a wide range of growers.

In general products hydrocooled should tolerate being wetted and not be damaged by falling water or disinfectants that it may contain, hence hydrocooling is recommended for produce for which washing is part of their market preparation. A risk associated with most hydrocoolers is the decay hazard associated with recirculated water, which leads to the possibility of decay producing organisms accumulating in the system, resulting in the contamination of the cooled produce. To prevent this from occurring, mild disinfectant such as chlorine at concentrations of 100 ppm (measured as hypochlorous acid) or approved phenol compounds are used and therefore produce cooled by this technique must not be affected by the use of these chemicals. One of the chief benefits of hydrocooling is that it is seen to prevent loss of moisture during the cooling process. Another advantage of this technique is that it is very rapid in contrast to other pre-cooling techniques available. Field heat can be removed in 20-30 min using hydrocooling instead of several hours normally needed for forced air-cooling. Hydro-air cooling is an important and specialized area of hydrocooling in which a mixture of refrigerated air and water in a fine mist spray is circulated around and through stacks of the produce. The advantage of hydro-air cooling is the reduced water requirements and the potential for improved sanitation. In hydro-air cooling the ratio of air-water influences the heat transfer capability of the cooling system and the applicability of certain products to this technique.

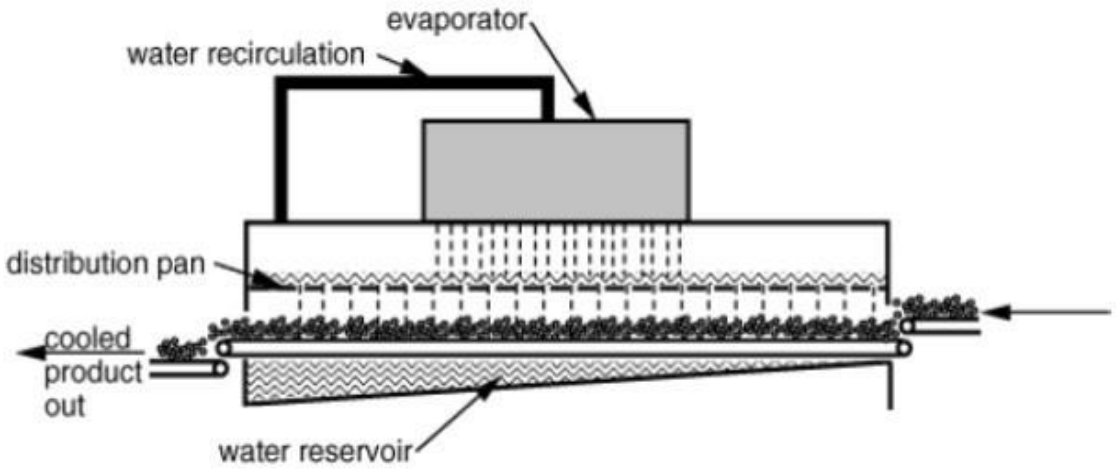


Figure. 17. Cut-away side view of a continuous-flow shower-type hydrocooler

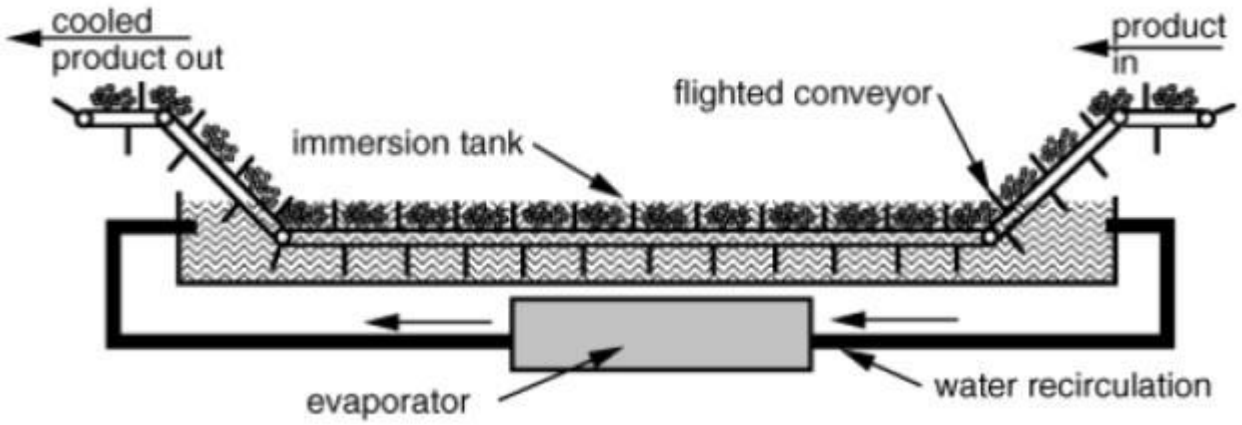


Figure.18. Cut-away side view of a continuous-flow immersion hydrocooler

Shower coolers distribute water using a perforated metal pan that is flooded with cold water from the refrigeration evaporator. Shower type coolers can be built with a moving conveyor for continuous flow operation, or they can be operated in a batch mode. Immersion coolers are suited for product that sinks in water. They usually cool slower than shower coolers because water flows at slower rates past the product. Water is a better heat-transfer medium than air and, consequently, hydrocoolers cool produce much faster than forced-air coolers. In well-designed shower coolers, small diameter produces, like cherries, cool in less than 10 min. Large diameter products like melons cool in 45 to 60 min. Immersion coolers usually have longer cooling times than shower coolers because water speed past produce is slower. Packages for hydro-cooled produce must allow vertical water flow and must tolerate water contact. Plastic or wood containers work well in hydrocoolers. Corrugated fiberboard must be wax dipped to withstand water contact. Hydro-coolers cause no moisture loss in cooling. In fact, they can rehydrate slightly wilted product.

4.1.7 Ice cooling: In ice cooling, crushed or fine granular ice is used to cool the produce. The ice is either packed around produce in cartons or sacks, or it is made into a slurry with water and injected into waxed cartons packed with produce. The ice then fills the voids around the produce. Before the advent of comparatively modern precooling techniques, contact or package icing was used extensively for precooling produce and maintaining temperature during transit. Although, unlike other cooling methods ice not only removes heat rapidly when first applied, it continues to absorb heat as it melts. There are a variety of different methods in which ice is applied to the produce so as to achieve the desired cooling effect. Package icing involves direct placement of slush, flaked, or crushed ice over the product in shipment containers. This method is sufficient where it is used; however, it can result in uneven cooling because the ice generally remains where it was placed until it has melted. In liquid icing, ice slurry is used instead of plain crushed ice as it can sustain cooling requirements better. Liquid icing may be considered a hybrid of package icing and hydrocooling. The simplest form of liquid icing is where a mixture of water and finely crushed ice is pumped into open containers travelling along a conveyor under an injection nozzle. If produce has been packed and palletised in the field, the liquid ice can be injected into the packages through vents or hand openings. Liquid-icing distributes the ice throughout the commodity, i.e., placed in each individual package better, thus achieving improved ice/produce contact and hence better and more uniform cooling. Another method of icing is top icing or placing ice on top of packed containers. This is only used occasionally to supplement another cooling method. Because corrugated containers have largely replaced wooden crates, the use of top icing has decreased. Wax-

impregnated corrugated containers have allowed the use of icing of products after packaging to continue; however, it is being replaced by hydrocooling and vacuum cooling. The major advantage of icing is that produce does not dry as it is cooled. Another advantage is that in addition to removing field heat, package icing can maintain low product temperature during transit and therefore refrigerated transportation may not be necessary for short transport duration. Although icing requires relatively small outlays of special equipment, a large weight of ice must be shipped, thus increasing costs, and also water-proof containers which are more expensive than normal are required for this cooling technique. Another ambiguity of icing is that icing wets the produce and thus the surface of warm wet produce provides an excellent site for post-harvest diseases and soft rots. Therefore, it is essential that produce be not allowed to rewarm once it is iced. Another drawback of this method of pre-cooling is that after the ice has melted, the package is left only partly full. Ice cooling is faster than hydrocooling because contact with the produce is good, and ice has a higher heat removal capacity than water. As in hydro-cooling, ice cooling requires particular attention to water quality and sanitation.

4.1.8 Vacuum cooling: Rapid cooling of horticultural produce can be carried out with vacuum cooling. Vacuum cooling is achieved by the evaporation of moisture from the produce. The evaporation is encouraged and made more efficient by reducing the pressure to the point where boiling of water takes place at a low temperature.

In the vacuum cooling process the pressure in the vacuum chamber is reduced from atmospheric to about 20 mbar and, during this time, evaporation is slow and relatively little cooling takes place, i.e., temperature of the produce remains constant until saturation pressure at this temperature is reached. At approximately this pressure the `flash point' occurs; this is the point where the water in the produce begins to vaporize, i.e., produce begins to lose moisture and cool rapidly. For example, if the produce had an ambient field heat of 20 degree Celsius then the `flash point' would occur at 24 mbar. At this point the wet bulb temperature sharply increases as the air in the tank is evacuated and is replaced by the evaporated water vapour. This vapour has to be removed quickly in order to keep the overall cooling cycle to a reasonably length, and this is accomplished by the use of a condenser in the chamber. The pressure is further reduced, and cooling continues until a pressure corresponding to the desired final saturation temperature is reached. In practice, most operators do not reduce the pressure below 6.09 mbar (saturation pressure corresponding to a temperature 0 degree C because of the extra work involved and because of the freezing potential at reduced pressures.

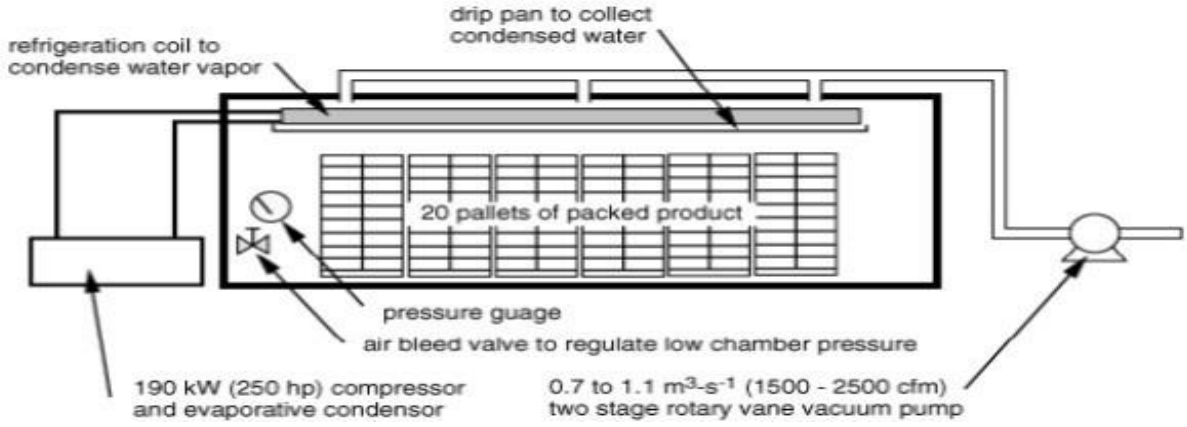


Figure.19. Key components of a 20-pallet capacity vacuum cooler

The heat required to vaporize this water is removed from the product surface, hence the cooling rate is limited by heat and mass transfer, i.e., evaporation rate of water from the products surface and inner tissues. Therefore, the rate of cooling depends primarily upon the ratio of surface area of the product to its weight or volume, the ease with which water is given up from the product tissues, the rate of vacuum drawn in the flash chamber and the temperature of the load at the start. Many investigations agree that vacuum cooling of fresh produce by the rapid evaporation of water from the product works best with products having a high ratio of surface to volume. Since water is seen as the primary refrigerant, it is a safe assumption that the quantity of heat removed from the product is directly related to the amount of water evaporated off the products surface.

Vacuum cooling is greatly influenced by the surface area to mass ratio and the ease with which water is released from the products tissues. Large temperature gradients develop in products with a low surface area to mass ratio. In order to prevent surface freezing before the product is cooled to the required temperature, a ``bouncing'' procedure is practiced. This is accomplished by switching the vacuum pump off and on to keep the saturation temperature above freezing. One disadvantage of vacuum cooling is that it causes weight loss in the produce being cooled due to the removal of moisture. Temperature reductions average 5 to 5.5 degree Celsius for each 1% of weight loss, regardless of the product cooled. This small loss in weight is usually acceptable in the products that are cooled by this technique. A way of reducing this loss is by spraying free water on to the product before it is placed into the cooling chamber. Special vacuum cooler `hydrovac' have been developed, which have a built-in water spray activated towards the end of the cooling operation and thus minimizes weight loss. The rapid cooling achievable by the use of vacuum cooling makes it more appealable and gives it a distinct advantage over other cooling techniques. Examples of its speed of removing heat are given previously. Another advantage is that vacuum cooling can achieve uniform cooling throughout a package or lot of produce, provided the package or box is not hermetically sealed to allow free evaporation.

4.1.9 Cryogenic cooling: The use of the latent heat of evaporation of liquid nitrogen or solid CO2 (dry ice) can produce `boiling' temperatures of -196- and -78-degree C, respectively. This is the basis of cryogenic precooling. In cryogenic cooling, the produce is cooled by conveying it through a tunnel in which the liquid nitrogen or solid CO2 evaporates. However, at the above temperatures the produce will freeze and thus be ruined as a fresh market product. This problem is prevented by careful control of the evaporation rate and conveyor speed. Cryogenic cooling is relatively cheap to install but expensive to run. Its main application is in cooling crops such as soft fruits, which have a seasonal production period. Hence, by using cryogenic cooling the grower would not incur the high capital costs associated with alternative cooling techniques over such period of use. The high cost of liquid nitrogen, dry ice and other suitable non-toxic refrigerants make this process most suitable for relatively expensive products.

4.1.10 Evaporative Cooling: Evaporative cooling is an inexpensive and effective method of lowering produce temperature. It is most effective in areas where humidity is low. Dry air is drawn through moist padding or a fine mist of water, then through vented containers of produce. As water changes from liquid to vapor, it absorbs heat from the air, thereby lowering the produce temperature. The incoming air should be less than 65 percent relative humidity for effective evaporative cooling. It will only reduce temperature, 10-15°F. This method would be suitable for warm-season crops requiring warmer storage temperatures (45-55°F), such as tomatoes, peppers, cucumbers, or eggplant.

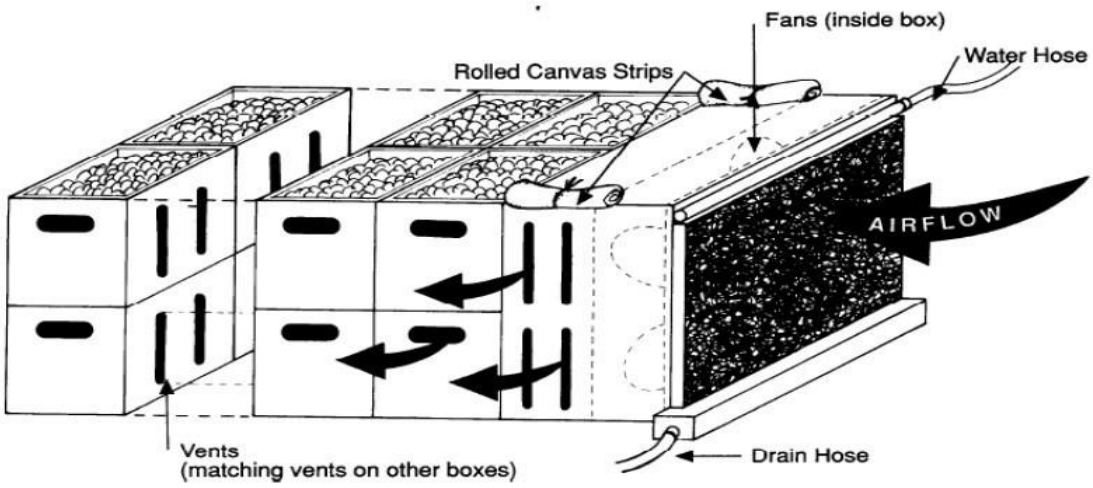


Figure. 20. Evaporative Cooling

4.2. Washing, Cleaning and Trimming: Simple postharvest operation such as cleaning, washing and trimming makes produce very fresh after harvest and make convenient for the produce to sales in the market. Preparation for the fresh market starts with dumping onto packinghouse feeding lines. Dumping may be dry or in water (Fig. 20 and 21). In both cases it is important to have drop decelerators to minimize injury as well as control the flow of product. Water dipping of produces causes less bruising and can be used to move free-floating fruits. However, not all products tolerate wetting. A product with a specific density lower than water will float, but for the produce which sinks, salt (NaCl) is diluted in the water to improve floatation.

Figure. 20. Dry dumping of lemons

Figure. 21. Water dumping of apple

Cleaning

Most of the fruits and underground vegetables like beetroot, radish, carrot, ginger etc. when harvested are with soil/mud/latex/pesticides/dried/pest infested/diseases and look dirty. Cleaning and washing makes them marketable. After harvest they should be gently rubbed with wet cloth/dry air and then washed properly to remove all soil and secondary roots. Unclean produce may contain bacteria and fungus which can damage the produce during transit and storage.

- Very small produce is mechanically removed by mesh screens, pre-sizing belts or chains.
- Bruised, rotted, mis-shaped produce, wilted or yellow leaves are usually removed by hand.
- Garlic and onions are topped to remove the dry foliage attached to the bulbs (Fig. 22).
- In many crops soil and loose parts are removed by brushing (Fig.23, 24 and 25).

- For produce such as kiwifruits and avocadoes, dry brushing may be sufficient to clean the produce. Soft brush bristles are preferred in washing, the stiffness must be just enough to remove the dirt without injuring the fruits. The brush speed should not exceed 200 rpm.

Figure 22 Topping onions before grading

Figure. 23 Brushing and hand removal of damaged fruits before grading

Figure. 24 Spiral wound cylinder brushes.

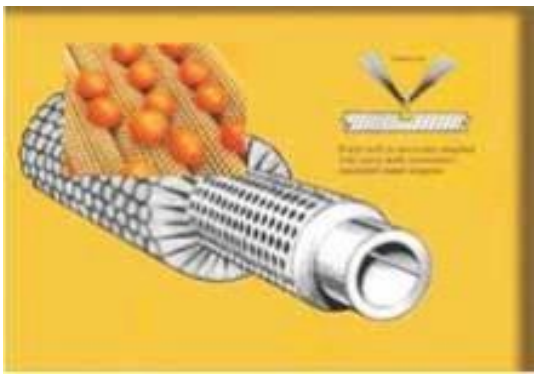


Figure 25 Staple set cylinder brushes

Washing

- Washing of fruits and vegetables is done to remove adhering dirt, stains, insects, molds and sometimes spray residues.
- Washing not only help in cleaning and making the vegetables/fruits fresh and also improves appearance, it also helps in extending the shelf life of the produce.
- Washing is done manually under tap water or in a wash tank using soft muslin cloth.
- Produce should be thoroughly washed with clean water (preferably with 100 - 150 ppm hypochlorite/chlorine) or soap or calcium hydroxide. Most efficient detergent used is sodium metabisulphate.
- After washing they are then wiped with dry muslin cloth or air-dried to remove excess surface moisture. Under automated systems, the produce passes under a spray washer on a moving conveyor roller.
- Thumb rule is to use 1 to 2 ml of chlorine bleach per liter of water gives 100-150 ppm of Cl. pH of the water must be around 6.5 to 7.5.

- Sanitation is essential, both to control the spread of disease from one item to another, and to limit spore buildup in wash water or in the packinghouse air. Fungicide may be used as post-harvest dip to control diseases and disorder.
- Excess water should be removed from the produce to avoid rotting. In crops where water dipping is possible, differential floatation could be used to separate rejects.
- Root and tuber vegetables are often washed to remove adhering soil.
- The typical fruit washer B depicted in Fig. 11.7

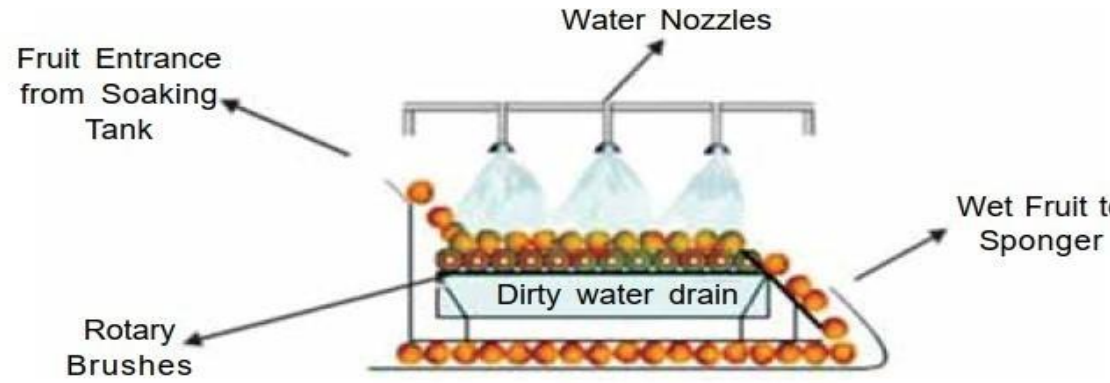


Figure. 26 A typical fresh produce washing machine

The Choice of Brushing and/or Washing will Depends on the Type of Commodity and Contamination.

a) Wash before cooling and packing- Carrot(soil), cucumbers, leafy greens, tomatoes
b) Wash to remove latex, reduce staining - mangoes(sap), bananas(debris/sap)
c) Wash after storage - sweet potatoes, potatoes, carrots
d) Dry brush after curing or storage - onions, garlic, kiwifruit
e) Brushing and wiping - Melons
f) Do not wash -strawberry, beans, melons, cabbage, okra, peas, pepper, summer squash etc.

Dry Cleaning

In some cases, cleaning is done by dry brushing instead of washing. Eg. Removal of white cottony mealy bugs attached in between the surface holes of custard apple fruits. Some fruits and vegetables are just wiped with clean dry cloth. Fruits and vegetables which are not suitable for washing are: onion, garlic, okra, grapes, strawberry, mushrooms, etc.

Trimming

Removal, trimming and cutting of all undesirable leaves/ stem/ stalks/ roots/other non-edible or unmarketable parts is called dressing. Dressing makes vegetables attractive and marketable. Trimming is done especially in vegetables and flowers to remove unwanted, discolored, rotting and insect damaged parts (e.g., cabbage, cauliflower, spinach, lettuce, rose, chyrysanthemum, gladiolus, tuberose etc.) or parts that may favour deterioration or damage during later handling. In case of grapes, trimming of bunches is done to remove the undersize, immature, dried, split and damaged berries. Trimming and removal of decaying parts are preferably done prior to washing. Trimming enhances visual quality, minimizes water loss and other deteriorative processes. Trimming reduces the likelihood of diseases or their spread, facilitates packaging and handling, and reduces damage for other produce.

4.3. Sorting, Grading and Sizing: Sorting is done by hand to remove the fruits which are unsuitable to market or storage due to damage by insects, diseases, or mechanical injuries. The remainder crop product is separated into two or more grades on the basis of the surface color, shape, or visible defects. For e.g., in an apple packing house in India 3 grades viz. Extra Fancy, Fancy and standard may be packed for marketing. The fourth "cull" grade is meant for processing. After sorting and grading, sizing is done either by hand or machine. Machine sizers work on two basic principles: weight and diameter. Sizing on the basis of fruit shape and size are most effective for spherical (Oranges, tomato, certain apple cultivars) and elongated (Delicious apples and European pears or of non-uniform shape) commodities, respectively.

Sorting

Sorting is done by hand to remove the fruits and vegetables which are unsuitable to market or storage due to damage by mechanical injuries, insects, diseases, immature, over-mature, misshapen etc. This is usually carried out manually and done before washing. By removing damaged produce from the healthy ones, it reduces losses by preventing secondary contamination. Sorting is done either at farm level or in the pack-houses. In sorting, only sensory quality parameters are taken into consideration.

The following illustrations represent three types of conveyors used to aid sorting of produce.

- The simplest is belt conveyor, where the sorter must handle the produce manually in order to see all sides and inspect for damage.

- Push bar conveyor causes the produce to rotate forward as it is pushed past the sorters.

- Roller conveyor rotates the produce backward as it moves past the sorter.

Sizing

Before or after sorting, sizing is done either by hand or machine. Machine sizers work on two basic principles: weight and diameter. Sizing on the basis of fruit shape and size are most effective for spherical (oranges, tomato, certain apple cultivars) and elongated (Delicious apples and European pears are of non-uniform shape) commodities, respectively.

Mechanisms/Types of sizing

A. **Diverging belts/rope grader:** The different speed of belts makes produce rotate besides moving forward to a point where produce diameter equals belt/rope separation. E.g., Cucumbers, Gherkins, Pineapples, and large root vegetables (Figure. 27).

B. Sizing rollers: with increased spaces between rollers (Figure. 28) E.g., Citrus.

C. **Handheld template**: Sizing can be performed manually using rings of known diameter (Figure. 30).

D. Sizing by weight: sorting by weight is carried out in many crops with weight sensitive trays. These automatically move fruit into another belt aggregating all units of the same mass. Individual trays deposit fruit on the corresponding conveyor belt (Figure 29). Eg. Citrus, apples and pear and irregular fruits

E. **Mesh screens**: e.g., potato, onion, anola etc.

Fig. 27. Sizing onion bulbs by diverging belts/rope

Figure.28 Sizing by rollers of increasing distance between them

Figure. 29 Sizing by weight.

Figure 30. Sizing with rings of known diameters

Grading

The produce is separated into two or more grades on the basis of the surface colour, shape, size, weight, soundness, firmness, cleanliness, maturity & free from foreign matter /diseases insect

damage /mechanical injury. For e.g., Apple - I. Extra Fancy; II. Fancy; III. Standard; IV. Cull (for processing). Grading may be done manually or mechanically. It consists of sorting product in grades or categories based on weight/size.

Systems of Grading: Static and Dynamic

A. Static systems: These are common in tender and/or high value crops. Here the product is placed on an inspection table where sorters remove units which do not meet the requirements for the grade or quality category (Figure 31).

Figure 31. Static quality grading system

Figure. 32. Dynamic quality grading system

Figure. 33 Grading of Gherkin

B. The dynamic system: Here product moves along a belt in front of the sorters who remove units with defects (Figure 32). Main flow is the highest quality grade. Often second and third grade quality units are removed and placed onto other belts. It is much more efficient in terms of volume sorted per unit of time. However, personnel should be well trained. This is because every unit remains only a few seconds in the worker's area of vision. e.g., Onion grading There are two types of common mistakes: removing good quality units from the main flow and more frequently, not removing produce of doubtful quality.

New Innovation in Grading Systems

a) Computerized weight grader - operate on the basis of tipping buckets that drops to release the pre weighed item at a particular position. - Apples, citrus
b) Video image capture & analysis-used for size, colour & external defect grading-coffee bean, apple NIR Spectrometers - to assess the TSS non - destructively in apple and stone fruits
c) X-ray imaging and Computer aided tomography
d) MRI - Magnetic Resonances Imaging
e) Spectroscopy
f) Acoustic methods
g) Volatile emission analysis

4.4. Curing: Curing is an effective operation to reduce the water loss during storage from hardy vegetables viz, onion, garlic, sweet potato, and other tropical root vegetables. The curing methods employed for root crops are entirely different than that from the bulbous crops (onions and garlic). The curing of root and tuber crops develops periderms over cut, broken or skinned surfaces wound restoration. It helps in the healing of harvest injuries, reduces loss of water, and prevents the infection by

decay pathogens. Onions and garlic are cured to dry the necks and outer scales. For the curing of onion and garlic, the bulbs are left in the field after harvesting under shade for a few days until the green tops, outer skins and roots are fully dried.

Advantages

- It helps in wound healing of harvest and handling injuries through skin hardening
- Reduce water losses
- Prevent infection from pathogen

Curing Procedure

- Curing is normally undertaken in the field, but in some case curing structure are employed.
- Produce can be cured in the field by piling them in a partially shaded area. Cut grass or straw can serve as insulating material, while, covering the pile with canvas, burlap, or woven grass matting. This covering will provide sufficient heat to reach high temperatures and high relative humidity. The stack can be left in this state for up to four days.
- Curing in potato starts with deposition of suberin in parenchymatous cell just below the damaged area of the tuber.
- Suberin (a waxy waterproof substance found in the cell walls of many plants, especially corky in nature) is a group of fatty acids which provides initial protection to the tuber against water loss and infection.
- Subsequently, below the suberized cells a meristematic layer of cells is formed which is the periderm, also called as cork cambium. This produces new cells which seal off the damaged area. But these processes are temperature and humidity dependent**.**
- Eg. Curing of potato takes place in 1 days at 21 degree Celsius; 2 days at 15 degree Celsius; 3 days at 10 degree Celsius; 5-8 days 5 degree Celsius.

Optimum condition for curing of vegetables

Commodity	Temp(°C)	RH (%)	Days for curing
Potato	13-17	>85	7- 15
Sweet potato	27-33	>90	5- 7
Yam	32-40	>90	1- 4
Cassava	30-35	>80	4- 7
Garlic and onion	35-45	60-75	0.5-1 warm forced air

When extreme conditions in the field exist, such as heavy rain or flooded terrain, and curing facilities are not available, a temporary tent must be constructed from large tarpaulins or plastic sheets to cure the produce and avoid heavy loss.

Figure 34. Field curing of Yams

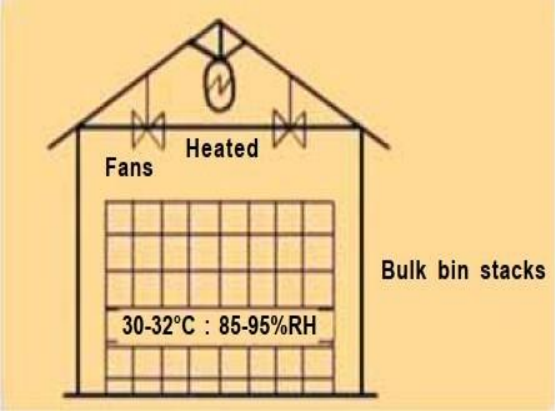


Figure 35. Typical curing houses for roots and tubers

4.5. Waxing: Fruits and vegetables have a natural waxy layer on the whole surface (excluding under-ground ones). This is partly removed by washing. Waxing is especially important if tiny injuries and scratches on the surface of the fruit or vegetable are present and these can be sealed by wax**.**

Waxes - are esters of higher fatty acid with monohydric alcohols and hydrocarbons and some free fatty acids. Waxing generally reduces the respiration and transpiration rates, but other chemicals such as fungicides, growth regulators, preservative can also be incorporated specially for reducing microbial spoilage, sprout inhibition etc. However, it should be remembered that waxing does not improve the quality of any inferior horticulture product, but it can be a beneficial in addition to good handling. A protective edible coat on fruit and vegetable which protect them from transpiration losses and reduce the rate of respiration is called waxing'.

Skin coating (Protective coating) - is defined as artificial application of a very thin film of wax or oil or other material to the surface of the fruits or vegetables as an addition to or replacement for the natural wax coating.

Advantages of Wax Application are:

- Reduced moisture losses and retards wilting and shriveling during storage
- Reduced weight loss
- Prevents chilling injury and browning
- Protect produce from bruising
- Reducing respiration rate - by creating diffusion barrier between fruit and surrounding as a result of which it reduces the availability of O2 to the tissues.
- Protects fruits from micro-biological infection
- Considered a cost-effective substitute in the reduction of spoilage when refrigerated storage is unaffordable.
- Carrier agent - used as carrier for sprout inhibitors, growth regulators and preservatives.
- Increase in the shelf life
- Mango fruits treated with wax emulsion containing 8 to 12% solids have one- or two-week's longer storage life than the untreated ones.

Specifications of a Desirable wax

- The selected wax material should provide a lasting shine
- Must be manufactured from food grade materials
- It should not develop any off-flavour and resistant to chalking. This can be determined by cooling waxed fruit to 0°C and allowing moisture to condense on fruit on removal from cold room.
- It should reduce weight loss of commodity by 30% to 50%
- Rapid drying, competitive price and easy clean up.

Principle of Fruit Coating

Fruit coating results in the restriction of the gas exchange between the fruit and surrounding atmosphere. This causes a buildup of CO2 and a depletion of O2 with in the fruit, thus causing an effect similar to CAS (controlled atmosphere storage).

If surface coatings and their concentration are not selected properly, the respiratory gas exchange through fruit skins is excessively impaired leading to development of off-odours and off-flavours. Over waxing also results in abnormal ripening and softening that affects the marketing of such fruits.

Fruit coatings can be formulated from different materials including lipid, resins, polysaccharides, proteins, and synthetic polymers. Most coatings are a composite of more than one film with the addition of low molecular weight molecules such as polyols, that serve as plasticizers (increase the plasticity or fluidity of the material). Otherwise, coatings can be too brittle and will flake or crack on the coated product. Surfactants, antifoaming agents, and emulsifiers are also often used in coatings.

Fruits Suitable for Waxing

- **Immature fruit vegetables:** Cucumbers and Summer Squash
- **Mature fruit vegetables**: Eggplant, Peppers and Tomato, Potato, Pumpkin, Carrot, Snake Gourd, Coccinia and Capsicum
- **Fruits:** Apple, Avocado, Banana, Citrus (Orange, Mandarin, Lemon, Grapefruit), Guava, Mangoes, Melons, Papaya, Peaches, Pineapple etc.

Food grade waxes are used to replace some of the natural waxes removed in washing and cleaning operations and helps in reducing loss during handling and marketing. If produce is waxed, the wax coating must be allowed to dry thoroughly before further handling.

Types of Waxing

- **Natural waxing:** On the plant when fruit attains desired stage of maturity, nature provides them with thin coat of whitish substance, which is called bloom or natural waxing. Natural coat is clearly visible on fruits and disappears after harvest due to repeated handling of fruit. Ex: apple, pear, plum, mango and grapes.

- **Artificial waxing:** To Prolong the shelf life of produce some of the fruit and vegetables are dipped in a wax emulsion and then dried for few minutes. This process provides thin layer (<1 μ) of artificial wax on skin of the produce by which the small pores present on the skin are fully covered and reduce the transpiration and respiration process resulting in increased shelf life. Artificial wax also provides good shining and luster to the produce, which increases its market value. Artificial waxes like solvent waxes, water waxes and paste or oil waxes are used.

List of commercial waxes

	Waxes
1	Shellac
2	Carnauba wax
3	Bee wax
4	Polyethylene
5	Wood resins
6	Paraffin wax

Methods of Wax Application

Performance of waxing depends on method of application. Amount of wax applied, and uniformity of application are extremely important. Fruits should be damp dry prior to wax application to prevent dilution. Waxes should never be diluted with water. The following methods are commonly used.

1. **Spray waxing:** This is most commonly used method. Fruits and vegetables which move on the roller conveyor are sprayed with water-wax emulsion Figure 36 and 37. The waxed produce is dried in a current of air at 55°C. There are two types of spray waxing namely low pressure spraying and high-pressure atomizing.

Figure 36. Spraying of wax solution on commodity.

Figure 37. Wiping of wax counted commodity on conveyor.

2. **Dipping:** Here fruits are dipped in water wax emulsion of required concentration for 30 to 60 seconds. The fruits or vegetables could be waxed by keeping them in wire boxes holding about 100 fruits (30 kg) and dipping in 30-liter capacity tank containing wax emulsion. The fruits are then removed and allowed to dry under electric fan or in the open air or with warm air at 54 to 55°C. The produce should be turned periodically while drying.

3. **Foam waxing:** Foaming is a satisfactory means of application because it leaves a very thin coating of wax on the fruit after the water has evaporated. A foam generator is mounted over a suitable brush

head, and water is applied to the fruit or vegetable in them foam of foam. Spraying tends to waste wax, but it can be recovered in catch pans.

4. **Flooding:** Flooding is similar to dipping and is a safe and convenient method of application

Trade Name of Some Extensively used Waxes

- Citrashine@ from DECCO, India UPL
- Waxol -12 - Oil/ water-emulsion wax containing 12% solids
- Tal-Prolong
- Semper fresh
- Frutox - Emulsion of different waxes with 12 % solids.

Use of wax concentration on the fresh produce:

Conc. of wax (%)	Commodity
12	Carrot, brinjal, snake gourd, potato, cucumber, coccinia, capsicum, ribbed gourd, pine apple, guava and papaya
09	Tomato, lime, orange
08	Apple
06	Mango and musk melon

Quantity of wax emulsion at 12% concentration required for one mT. of commodity

Item	Wax emulsion (12%) in L
Orange	3.6
Mosambi	5.4
Mango(300-350gm)	3.6
Potato	7.9
Apple	5.4
Guava	5.7
Tomato	5.0
Banana	3.0
Lime	9.0

4.6. Packaging: The main function of packaging fruits, vegetables and flowers is to assemble the produce into convenient units for better handling and to protect them. A good package should aim at protection of produce from physical, physiological, and pathological deterioration throughout storage, transport, and marketing. In recent times, packaging is becoming an essential part of supply chain of horticultural crops because of the consumer's choice for convenience, appeal, information, and branding.

Benefits of Packaging

1. Packaging serves as an efficient handling unit
2. It serves as a convenient storage unit
3. Packaging protects quality and reduces waste
    - Protects from mechanical damages
    - Protects against moisture loss
    - May provide beneficial modified atmosphere
    - Provides clean produce
    - May prevent pilferage
4. Provides service and sales motivation
5. Reduces cost of transport and marketing
6. Facilitates use of new modes of transportation

Function of the Packaging

- To assemble the produce into convenient units for handling.
- To protect the produce during distribution, storage, and marketing.
- Presentation
- Preservation
- Containment - package contains the product with in it and prevents leakage etc.

Requirement for an Ideal Package

- Package should have sufficient mechanical strength to protect the content during handling, transportation, and stacking.
- It should be unaffected by moisture content, when wet and high RH for its strength.
- Stabilize and secure product against movement within the package while handling.
- Free from chemicals that could transfer to the produce and taint it or be toxic to the produce or to humans
- Meet handling & marketing requirement in terms of weight(light), size and shape (rectangle)
- Allow rapid cooling of the contents, and/or offer degree of insulation from the external heat/cold.
- Utilizes the gas barrier (e.g., plastic films) with sufficient permeability to respiratory gases as to avoid any risk of anaerobiosis (ventilation) and any bad odor.
- It must be easy to assemble, fill and close either by hand or by use of a simple machine
- Offer the security for the contents, and /or ease of opening and closing in some marketing situation (e.g., promotional activity)
- Facilitate easy disposal, reuse, or recycling.
- It should be easily transported when empty and occupy less space than when full Eg. Plastic boxes which nest in each other when empty Collapsible plastic crates, cardboard boxes, fiber or paper or plastic sacks.
- Package must be readily available.

Various packages used for packaging of fruits and vegetables are as follows:

(i). Wire-Bound Crates

Wooden-wire-bound crates are used for packaging of those vegetables which require hydrocooling. Because these are sturdy rigid with high stacking strength and are not affected by water (Figure 38) these are helpful for hydrocooling because of sufficient ventilation.

Figure 38. Wire-Bound Crates

(ii). Wooden Crates and Lugs

These are generally used for costly fruits i.e., apples, stone fruits especially by Himachal Pradesh and Jammu Kashmir (Figure 39). This is very sturdy and durable even for rough conditions. It has a good stacking strength which is required during long distance transportation and Easy for handling because of durability.

Figure. 39 Wooden Crates and Lugs

(iii). Wooden Baskets and Hampers

These are generally made up of veneer of different sizes and generally used for highly perishable commodities. These are durable and can be easily nested for transportation when empty.

Figure. 40 Wooden Baskets and Hampers

(iv). Corrugated Fiber board

This is the most accepted with different styles and weights and is made up of paperboard manufactured by Kraft process (Figure 41). Paper board is generally 0.020 cm thick and is generally made from unbleached pulp with a characteristic brown colour. Different types of paper board are made up of different grades. These are differentiated by thickness and weight. In addition to virgin wood fibres, Kraft paper may have some portion of synthetic fibers for additional strength, sizing, and other materials to give it wet strength and printability. Most fiber board contains some recycled fibres. Tests have shown that cartons of fully recycled pulp have about 75 percent of the stacking strength of virgin fibre containers. The use of recycled fibers will inevitably lead to the use of thicker walled containers. These are generally available in market as 3 ply, 5 ply, and 7 ply in which both the outer side are similar. Whereas sandwhich layer are in the form of pipelines which gives them more strength and cushioning. In 5 ply, three smooth layers and alternating with pipelines which gives it more firmness and cushioning.

Figure 41 Corrugated Fiberboard

(v). Double-faced corrugated fiberboard

Double-faced corrugated fiberboard is the predominant form used for produce containers. It is produced by sandwiching a layer of corrugated paperboard between an inner and outer liner (facing). Corrugated fiberboard manufacturer gives certificates on the bottom of containers to certify certain strength characteristics and limitations. Both cold temperatures and high humidity reduce the strength of fiberboard containers. Unless the container is specially treated, moisture absorbed from the surrounding air and the contents can reduce the strength of the container by as much as 75 percent. New anti-moisture coatings (both wax and plastic) are now available to substantially reduce the effects of moisture.

Figure 42 Double-Faced Fibreboard

(v). Waxed Fiberboard Cartons

Waxed fiberboard cartons (the wax is about 20 percent of fiber weight) are used for many produce items that must be either hydrocooled or iced.

Figure 43 Waxed Fiberboard Cartons

(vi). Paper and Mesh Bags

Consumer packs of potatoes and onions are about the only produce items now packed in paper bags. The more sturdy mesh bag has much wider use. In addition to potatoes and onions, cabbage, turnips, citrus, and some specialty items are packed in mesh bags. Sweet corn may still be packaged in mesh bags in some markets. In addition to its low cost, mesh has the advantage of uninhibited air flow. Good ventilation is particularly beneficial to onions. Supermarkets produce managers like small mesh bags because they make attractive displays that stimulate purchases. Bags of any type have several serious disadvantages. Large bags do not palletize well, and small bags do not efficiently fill the space inside corrugated fiberboard containers. Bags do not offer protection from rough handling. Mesh bags provide little protection from light or contaminants

Figure 44 Paper and Mesh Bags

(vii). Plastic Bags

These are the predominant material for almost all commodities. These are easily affordable and excepted by the consumers. It is also called polyethylene film. Film bags are clear, allowing the easily inspection of the materials.

Figure. 45 Plastic Bags

(viii). Plastic Stretch film

These films are generally used for consumer packaging as they can be stretched retains its elasticity. It protects the package from the lost of moisture and keep it fresh for longer times.

These types of films can be used for primary processed products and also helps to give rural employment as the farmer itself will do that packaging and will make available directly to consumers. Primary processing will also reduce the pollution and bulk transportations of commodities. This will also help urbanites to fulfil their needs of perishable commodities in easily handled way.

Figure 46 Plastic Stretch Film

(ix). Nylon Bags

These are commonly used for consumer packaging with good strength (Figure 11). These can be reused and recycled. These are available in different sizes with different strength and mesh. These are good enough for storage and packaging with less water content i.e., onion, elephant fruit and arbi etc.

Figure 47 Nylon Bags

4.7. Storage: A number of storage techniques (ground storage, ambient storage, refrigerated storage, air cooled storage, zero energy storage, modified atmospheric storage, hypobaric storage, and controlled atmosphere storage) are being used for fruits and vegetables depending upon the nature of the commodity and the storage period intended.

Traditional / Low-Cost Storage Technologies

1. In Situ/On Site/Natural or Field Storage: In Situ means delaying the harvest until the crop is required and is employed for the root, tuber, and rhizomes crops. Crops should be left in the soil until preparation for the market. The land where crop is grown remains occupied and new crop cannot be planted there. This is similar to how citrus and some other fruits are left on the tree. E.g.: Roots (carrots, sweet potato, and cassava) tubers (potato) and rhizomes (Ginger) (Figure 48).

Figure. 48 Field storage of onion in heaps

2. Sand and Coir: In India, potatoes are traditionally stored longer periods of time, which involves covering the commodity underground with sand.

3. Bulk Storage of Dried Bulb Crops: Onions, garlic, and dried produce are best suited to low humidity in storage (Fig.49 and 50). Onions and garlic will sprout if stored at intermediate temperatures. Pungent types of onions have high soluble solids and will store longer than mild or sweet onions, which are rarely stored for more than one month.

Commodity	Temp. °C	RH	Potential storage duration
Onions	0-5	65-70	6-8 months
	28-30	65-70	1 month
Garlic	0	70	6-7 months
	28-30	70	1 month
Dried fruits and vegetables	<10	55-60	6-12 months

Figure 49. Storage conditions for onion, garlic etc.

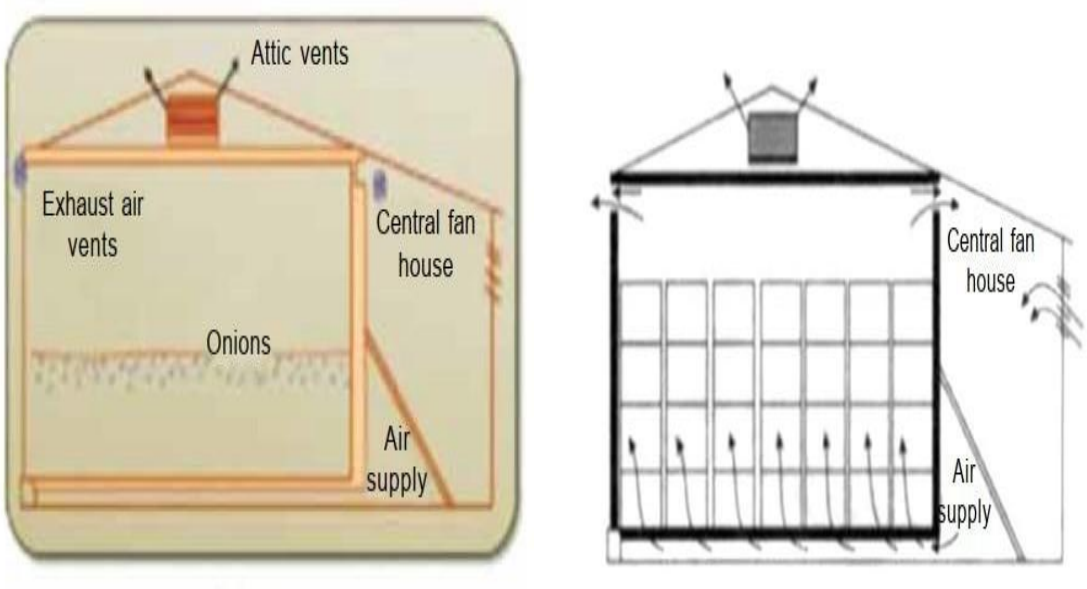


Figure 50. Bulk storage of dried bulb crops

For bulk storage of onions or garlic, ventilation systems should be designed to provide air into the store from the bottom of the room at a rate of 2 cubic feet /minute /cubic feet of produce. If produce is in cartons or bins, stacks must allow free movement of air.

4. Clamps: Clamps are being traditionally used for storing potatoes in certain parts of the world (Figure 51). A clamp is commonly built at the edge of the field. It has a width of around 1–2.5 m. After the piling up of potatoes in conical heaps, the dimensions are marked out. Quite often, a bed for the potatoes is made using straw on bare ground. The heap's central height is around one-third of the clamp's width, which is determined by the angle of repose of the heap. Rain runs over the structure through the straw, bent at the top to prevent possible spoilage. The compressed straw thickness must be in a range of 15 to 25 cm. After two weeks, the clamp is covered with soil up to a depth of 15–20 cm, which varies from place to place and depends on the environmental requirements.

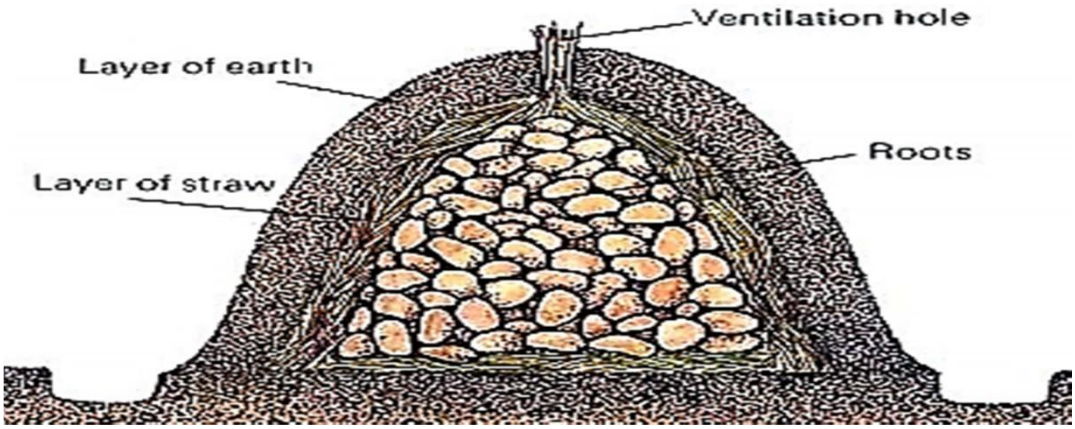


Figure 51. Root clamp cross-section

5. Pits: Pits are trenches in which a cavity is dug. These dug holes or cavities are lined with cut grass, wood shreds, sand, stubble, or soil (Figure 52). They are prepared at the boundaries of

the field and at an elevated point where there is a chance of less rainfall accumulation in the cultivated field. The product stays cooler as compared to the air temperatures because of submersion in the pits. Tubers, such as potato, carrot, sweet potato, onion, turnip, parsnip, cabbages, and beets are covered up with straw and soil until the market demand for the crop arises.

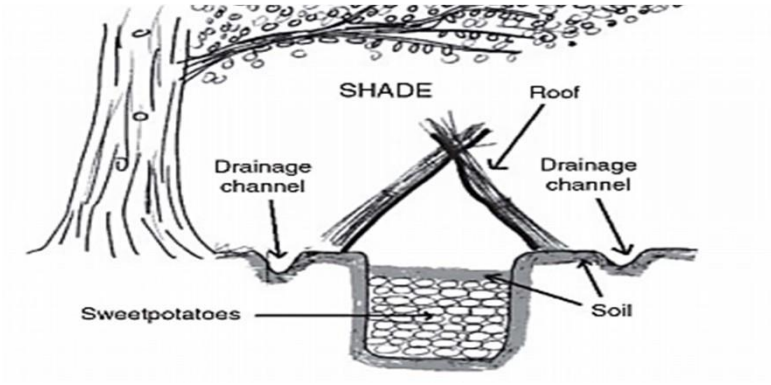


Figure 52. Pit storage for potatoes

6. Cellars/ Root cellars: Another example of the traditional storage system is the cellar (Figure 53 and 54). Cellars must ideally be dark, cold, and damp. They must be located by the basement walled-off area or garage having a significant area of optimum size and windows for proper ventilation. Following are some of the methods to construct storage cellars:

- Excavation of ground and building a shed or a house over the built cellar. Access can be provided from the top via a trap door
- Excavation through the hillsides is relatively easier and also permits rainwater drainage
- On rocky terrains, where it is difficult to excavate, a ground-level structure can be built. This structure, and the area surrounding it, can then be covered with rocks, earth, and sod.

The cellar can be used to store a wide variety of fresh produce, including beet, broccoli, potato, turnip, cabbage, carrot, pear, onion, Brussel sprouts, apple, and winter radish.

Figure 53. Storage of produce in the cellar

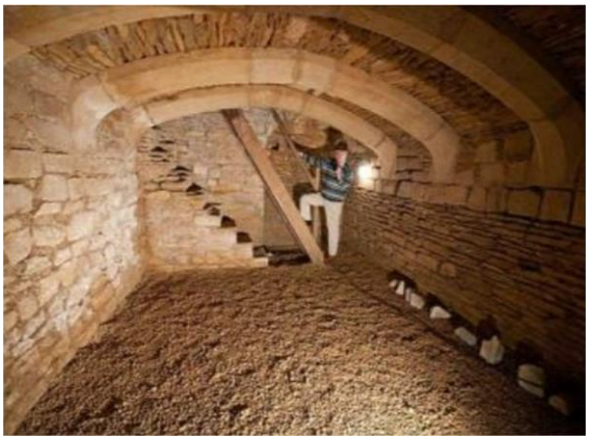


Figure 54. A view of the cellar

7. Zero Energy Cool Chambers: These chambers are designed on the principles of direct evaporative cooling. No electricity or power is required for their operation. The materials required for the

construction (bricks, sand, and bamboo) are also available easily (Figure 55). Zero energy cool chambers (ZECC) are double brick walled structures. The chamber walls are soaked in water, and the cavity is filled with sand. The chamber can be easily constructed by unskilled labour. This system can reduce the temperature of the crop by 10-15°C and maintain a high humidity of nearly 90%. ZECC hence helps in retaining the quality and enhancing the shelf life of the fresh products. Such practices can avoid middlemen or intermediaries in retail chains for small and marginal farmers by storing produce for a few days.

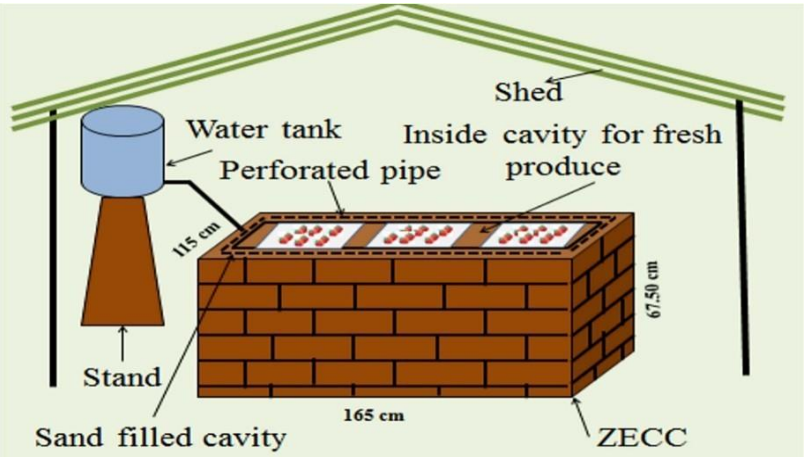


Figure 55. Zero energy cool chambers

4.7.1 Improved/ Modern storage methods/ High-cost storage technologies

Several improved and novel packaging and storage technologies have been experimented and commercialized for fruits and vegetables. These include refrigerated storage, CAS, MAP, and hypobaric storage. Important considerations for commercially adopting these technologies for bulk level include cost-effectiveness, eco-friendliness, product quality and applicability range, storage area to product volume ratio, skill requirement, process control, energy requirement and safety aspects. Some improved storage technologies for horticultural crops are discussed below:

1. Cold storage: The product's respirational intensity is directly linked to the optimum temperature of the storage space. Lowering of temperature leads to a decline in the rate of respiration of the produce, which further reduces the rate of biochemical reaction and improves the shelf life of the product. A cold storage facility (Figure 56) is the heart of the cold chain employed in the market of fresh produce. A cold chain ensures quality maintenance right from harvest to consumer use. Cold storage is usually a storage space maintained with the help of a non-toxic refrigerant and the walls insulated with a good insulator, like polyurethane foam (PUF) to minimize heat loss. Adequate storage is ensured by cold storages that maintain the desired fresh produce storage conditions combined with ventilation systems and humidity controllers.

Figure 56. Cold storage

Benefits

- Reduces respiration rate and thus perishability
- Reduces transpiration lessens shriveling, reduces water losses
- Decreases ethylene production slows ripening
- Enhances resistance to ethylene action
- Reduces microbial activity
- Decreases browning and maintains texture, nutrients, and flavor
- Postpones ripening and reduces natural senescence

2. CAS: In a CAS system, the produce is kept at reduced O2 and high CO2 concentrations with an appropriate temperature range and RH. Several commodities' shelf life can be extended up to 2-4 times the usual shelf life. The composition of CO2 and O2 levels in controlled atmosphere storage is kept within maintained and controlled levels in gas-tight containers or stores. The leakages in the walls and door of the storage area and the ripening produce's metabolic activities prompt a continuous change in the gas composition of the storage space. The gas composition is thus monitored periodically, and fresh air or nitrogen is input to maintain a predetermined level of headspace gas composition. It can also be done by passing the atmosphere of the store through a chemical for removing carbon dioxide. A system can be designed which initially flushes gases to lower the oxygen content and after that either injects carbon dioxide or allows it to cumulate through produce respiration. This atmosphere can then be maintained by scrubbing and ventilation. Table 1 describes the recommended conditions for some fruits and vegetables for which CAS is commercially used.

Table 1. Recommended conditions for controlled atmosphere storage of some horticultural crops

Fruits and vegetables	Temperature (C)	% Oxygen	% Carbon dioxide
Apple	0-5	2-3	1-2
Bananas	12-15	2-5	2-5
Cantaloupe	3-7	3-5	10-15
Kiwifruit	0-5	2	5
Lettuce	0-5	2-5	0
Nuts and dried fruits	0-25	0-1	0-100
Strawberry	0-5	10	15-20

Benefits of CAS

- It reduces the rate of respiration and ethylene production and hence, retards senescence of fresh products
- It decreases the responsiveness of fruits towards the ethylene action
- It prevents several physiological disorders, such as russet spotting in lettuce, chilling injury in a variety of products and some storage problems, including apple scalds
- The losses of some other vitamins, especially those susceptible to oxidation, can be prevented
- It has fungistatic effects and can prevent the incidence of various fungi and bacteria
- Insect attacks can be controlled
- It maintains the quantitative and qualitative aspects of the product for an extended period and hence helps improve their shelf life

5.0 Maturity Index for Fruits and Vegetables

The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. Some typical maturity indexes are described in following sections.

(a) Skin Colour: This factor is commonly applied to fruits since skin colour changes as fruit ripens or matures. Some fruits exhibit no perceptible colour change during maturation, depending on the type of fruit or vegetable. Assessment of harvest maturity by skin colour depends on the judgment of the harvester, but colour charts are available for cultivars, such as apples, tomatoes, peaches, chilli peppers, etc.

Figure. 57 skin colour changes as fruit ripens or matures

(b) Optical Methods: Light transmission properties can be used to measure the degree of maturity of fruits. These methods are based on the chlorophyll content of the fruit, which is reduced during maturation. The fruit is exposed to a bright light, which is then switched off so that the fruit is in total darkness. Next, a sensor measures the amount of light emitted from the fruit, which is proportional to its chlorophyll content and thus its maturity.

(c) Shape: The shape of fruit can change during maturation and can be' used as a characteristic to determine harvest maturity. For instance, a banana becomes more rounded in cross-sections and less angular as it develops on the plant. Mangoes also change shape during maturation. As the mango matures on the tree the relationship between the shoulders of the fruit and the point at which the stalk is attached may change. The shoulders of immature mangoes slope away from the fruit stalk; however, on more mature mangoes the shoulders become level with the point of attachment, and with even more maturity the shoulders may be raised above this point.

(d) Size: Changes in the size of a crop while growing are frequently used to determine the time of harvest. For example, partially mature cobs of Zea mays saccharata are marketed as sweet com, while even less mature and thus smaller cobs are marketed as baby com. For bananas, the width of individual fingers can be used to determine harvest maturity. Usually, a finger is placed midway along the bunch and its maximum width is measured with callipers; this is referred to as the calliper grade.

(e) Aroma: Most fruits synthesize volatile chemicals as they ripen. Such chemicals give fruit its characteristic odour and can be used to determine whether it is ripe or not. These doors may only be detectable by humans when a fruit is completely ripe, and therefore has limited use in commercial situations.

(f) Fruit Opening: Some fruits may develop toxic compounds during ripening, such as ackee tree fruit, which contains toxic levels of hypoglycine. The fruit splits when it is fully mature, revealing black seeds on yellow arils. At this stage, it has been shown to contain minimal amounts of hypoglycine or none at all. This creates a problem in marketing; because the fruit is so mature, it will have a very short post-harvest life. Analysis of hypoglycine 'A' (hyp.) in ackee tree fruit revealed that the seed contained appreciable hypo at all stages of maturity, at approximately 1000 ppm, while levels in the membrane mirrored those in the arils. This analysis supports earlier observations that unopened or partially opened ackee fruit should not be consumed, whereas fruit that opens naturally to over 15 mm of lobe separation

poses little health hazard, provided the seed and membrane portions are removed. These observations agree with those of Brown et al. who stated that bright red, full sized ackee should never be forced open for human consumption.

(g) Leaf Changes: Leaf quality often determines when fruits and vegetables should be harvested. In root crops, the condition of the leaves can likewise indicate the condition of the crop below ground. For example, if potatoes are to be stored, then the optimum harvest time is soon after the leaves and stems have died. If harvested earlier, the skins will be less resistant to harvesting and handling damage and more prone to storage diseases.

(h)Abscission: As part of the natural development of a fruit an abscission layer is formed in the pedicel. For example, in cantaloupe melons, harvesting before the abscission layer is fully developed results in inferior flavoured fruit, compared to those left on the vine for the full period.

(i) Firmness: Fruit may change in texture during maturation, especially during ripening when it may become rapidly softer. Excessive loss of moisture may also affect the texture of crops. These textural changes are detected by touch, and the harvester may simply be able to gently squeeze the fruit and judge whether the crop can be harvested. Today sophisticated devices have been developed to measure texture in fruits and vegetables, for example, texture analysers and pressure testers; they are currently available for fruits and vegetables in various forms. A force is applied to the surface of the fruit, allowing the probe of the penetrometer or texturometer to penetrate the fruit flesh, which then gives a reading on firmness. Handheld pressure testers could give variable results because the basis on which they are used to measure firmness is affected by the angie at which the force is applied. Two commonly used pressure testers to measure the firmness of fruits and vegetables are the Magness-Taylor and UC Fruit Firmness testers.

(j). Juice Content: The juice content of many fruits increases as the fruit matures on the tree. To measure the juice content of a fruit, a representative sample of fruit is taken and then the juice extracted in a standard and specified manner. The juice volume is related to the original mass of juice, which is proportional to its maturity. The minimum values for citrus juices are presented in Table 2.

Citrus fruit	*Minimum juice content (%)*
Naval oranges	30
Other oranges	35
Grapefruit	35
Lemons	25
Mandarins	33
Clementines	40

Table 2. Minimum juice values for mature citrus.

(j). Oil content and Dry Matter Percentage: Oil content can be used to determine the maturity of fruits, such as avocados. According to the Agricultural Code in California, avocados at the time of harvest and

at any time, thereafter, shall not contain in weight less than 8% oil per avocado, excluding skin and seed. Thus, the oil content of an avocado is related to moisture content. The oil content is determined by weighing 5-10 g of avocado pulp and then extracting the oil with a solvent in a distillation column (figure 58). This method has been successful for cultivars naturally high in oil content. A round flask is used for the solvent. Heat is supplied with an electric plate and water recirculated to maintain a constant temperature during the extraction process. Extraction is performed using solvents such as petroleum ether, benzene, diethyl ether, etc., a process that takes between 4-6 h. After the extraction, the oil is recovered from the flask through evaporation of the water at 105 degree Celsius in an oven until constant weight is achieved.

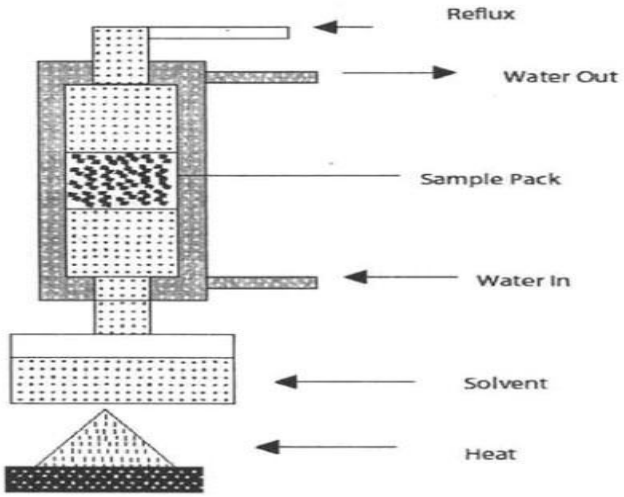


Figure 58. Distillation column used for oil determination

(k). Moisture Content: During the development of avocado fruit the oil content increases, and moisture content rapidly decreases.

(l). Sugars: In climacteric fruits, carbohydrates accumulate during maturation in the form of starch. As the fruit ripens, starch is broken down into sugar. In non-climacteric fruits, sugar tends to accumulate during maturation. A quick method to measure the amount of sugar present in fruits is with a brix hydrometer or a refractometer. A drop of fruit juice is placed in the sample holder of the refractometer and a reading taken; this is equivalent to the total amount of soluble solids or sugar content. This factor is used in many parts of the world to specify maturity. The soluble solids content of fruit is also determined by shining light on the fruit or vegetable and measuring the amount transmitted. This is a laboratory technique however and might not be suitable for village level production.

(m). Starch Content: Measurement of starch content is a reliable technique used to determine maturity in pear cultivars. The method involves cutting the fruit in two and dipping the cut pieces into a solution containing 4% potassium iodide and 1% iodine. The cut surfaces stain to a blue-black colour in places where starch is present. Starch converts into sugar as harvest time approaches. Harvest begins when the samples show that 65-70% of the cut surfaces have turned blue-black.

(n). Acidity: In many fruits, the acidity changes during maturation and ripening, and in the case of citrus and other fruits, acidity reduces progressively as the fruit matures on the tree. Taking samples of such

fruits and extracting the juice and titrating it against a standard alkaline solution, gives a measure that can be related to optimum times of harvest. Normally, acidity is not taken as a measurement of fruit maturity by itself but in relation to soluble solids, giving what is termed the brix: acid ratio.

(o). Specific Gravity: Specific gravity is the relative gravity, or weight of solids or liquids, compared to pure distilled water at 62°F (16.7°C), which is considered unity. Specific gravity is obtained by comparing the weights of equal bulks of other bodies with the weight of water. In practice, the fruit or vegetable is weighed in air, then in pure water. The weight in air divided by the weight in water gives the specific gravity. This will ensure a reliable measure of fruit maturity. As a fruit matures its specific gravity increases. This parameter is rarely used in practice to determine time of harvest but could be used in cases where development of a suitable sampling technique is possible. It is used however to grade crops according to different maturities at post-harvest. This is done by placing the fruit in a tank of water, wherein those that float are less mature than those that sink.

6.0 Harvesting Container

Harvesting containers must be easy to handle for workers picking fruits and vegetables in the field. Many crops are harvested into bags. Harvesting bags with shoulder or waist slings can be used for fruits with firm skins, like citrus fruits and avocados. These containers are made from a variety of materials such as paper, polyethylene film, sisal, hessian, or woven polyethylene and are relatively cheap but give little protection to the crop against handling and transport damage. Sacks are commonly used for crops such as potatoes, onions, cassava, and pumpkins. Other types of field harvest containers include baskets, buckets, carts, and plastic crates. For high-risk products, woven baskets and sacks are not recommended because of the risk of contamination.

6.1 Tool for Harvesting

Depending on the type of fruit or vegetable, several devices are employed to harvest produce. Commonly used tools for fruit and vegetable harvesting are secateurs or knives, and handheld or pole mounted picking shears. When fruits or vegetables are difficult to catch, such as mangoes or avocados, a cushioning material is placed around the tree to prevent damage to the fruit when dropping from high trees. Harvesting bags with shoulder or waist slings can be used for fruits with firm skins, like citrus and avocados. They are easy to carry and leave both hands free. The contents of the bag are emptied through the bottom into a field container without tipping the bag. Plastic buckets are suitable containers for harvesting fruits that are easily crushed, such as tomatoes. These containers should be smooth without any sharp edges that could damage the produce. Commercial growers use bulk bins with a capacity of 250-500 kg, in which crops such as apples and cabbages are placed, and sent to large-scale packinghouses for selection, grading, and packing.

7. Packing in the Field and Transport to Packinghouse

Careful harvesting, handling, and transporting of fruits and vegetables to packinghouses are necessary to preserve product quality for example berries picked for the fresh market are often mechanically harvested and usually packed into shipping containers.

7.1 Containers: Harvesting containers must be easy to handle for workers picking fruits and vegetables in the field. Many crops are harvested into bags. Harvesting bags with shoulder or waist slings can be

used for fruits with firm skins, like citrus fruits and avocados. These containers are made from a variety of materials such as paper, polyethylene film, sisal, hessian, or woven polyethylene and are relatively cheap but give little protection to the crop against handling and transport damage. Sacks are commonly used for crops such as potatoes, onions, cassava, and pumpkins. Other types of field harvest containers include baskets, buckets, carts, and plastic crates. For high-risk products, woven baskets and sacks are not recommended because of the risk of contamination.

7.2. Polyethylene bags: Clear polyethylene bags are used to pack banana bunches in the field, which are then transported to the packinghouse by means of mechanical cableways running through the banana plantation. This technique of packaging and transporting bananas reduces damage to the fruit caused by improper handling.

Figure. 58 Polyethylene Bags

7.3 Plastic field boxes: These types of boxes are usually made of polyvinyl chloride, polypropylene, or polyethylene. They are durable and can last many years. Many are designed in such a way that they can nest inside each other when empty to facilitate transport and can stack one on top of the other without crushing the fruit when full.

Figure. 59 Plastic field boxes

7.4 Wooden field boxes: These boxes are made of thin pieces of wood bound together with wire. They come in two sizes: the bushel box with a volume of 2200 in3 (36052 cm3) and the half-bushel box. They are advantageous because they can be packed flat and are inexpensive, and thus could be non-returnable.

Figure 60 Wooden field boxes

7.5. Bulk bins: Bulk bins of 200-500 kg capacity are used for harvesting fresh fruits and vegetables. These bins are much more economical than the field boxes, both in terms of fruit carried per unit volume and durability, as well as in providing better protection to the product during transport to the packinghouse. They are made of wood and plastic materials. Dimensions for these bins in the United States are 48 x 40 in, and 120 x 100 cm in metric system countries. Approximate depth of bulk bins depends on the type of fruit or vegetable being transported (Table 5)

Figure.61 Bulk bins

Commodity	*Depth (cm)*
Citrus	70
Pears, apples	50
Stone fruits	50
Tomatoes	40

Table 4. Approximate depth of bulk bins

8.0 Operations Prior to Packaging

Fruits and vegetables are subjected to preliminary treatments designed to improve appearance and maintain quality. These preparatory treatments include cleaning, disinfection, waxing, and adding of color.

(i**). Cleaning:** Most produce receives various chemical treatments such as spraying of insecticides and pesticides in the field. Most of these chemicals are poisonous to humans, even in small concentrations. Therefore, all traces of chemicals must be removed from produce before packing. The fruit or vegetable passes over rotary brushes where it is rotated and transported to the washing machine and exposed to the cleaning process from all sides.

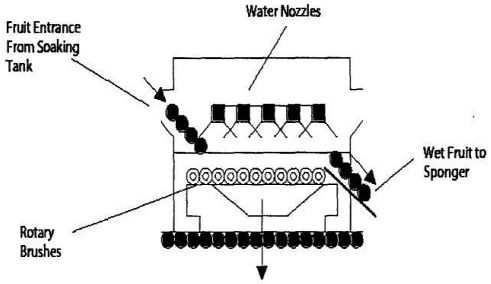


Figure. 62 Typical Produce washing machine

From the washing machine, the fruit passes onto a set of rotary sponge rollers (similar to the rotary brushes). The rotary sponges remove most of the water on the fruit as it is rotated and transported through the sponger.

(ii). **Disinfection:** After washing fruits and vegetables, disinfectant agents are added to the soaking tank to avoid propagation of diseases among consecutive batches of produce. In a soaking tank, a typical solution for citrus fruit includes a mixture of various chemicals at specific concentration, pH, and temperature, as well as detergents and water softeners. Sodium-ortho-phenyl-phenate (SOPP) is an effective citrus disinfectant but requires precise control of conditions in the tank. Concentrations must be kept between 0.05 and 0.15%, with pH at 11.8 and temperature in the range of 43-48°C. Recommended soaking time is 3-5 minutes. Deviation from these recommendations may have disastrous effects on the produce since the solution will be ineffective if the temperature or concentration is too low. Low concentrations of chlorine solution are also used as disinfectant for many vegetables. The advantage of this solution is that it does not leave a chemical residue on the product.

(iii). **Artificial waxing:** Artificial wax is applied to produce to replace the natural wax lost during washing of fruits or vegetables. This adds a bright sheen to the product. The function of artificial waxing of produce is summarized below:

- Provides a protective coating over entire surface.
- Seals small cracks and dents in the rind or skin.
- Seals off stem scars or base of petiole.
- Reduces moisture loss.
- Permits natural respiration.
- Extends shelf life.
- Enhances sales appeal.

9. General Dos and Don’ts for producing high quality of fruit and vegetables

- When choosing varieties, consider yields but also consider post-harvest characteristics and susceptibility to post-harvest pests and diseases.
- Plan planting / harvest dates, select cultivars that mature when market prices are high and demand for the product is high (Avoid periods of Glut)
- Use clean healthy, high quality planting materials
- Avoid over fertilization with Nitrogen (Reduces quality, increases susceptibility to decay-causing pathogens, insect damage and storage disorders.
- Take care with animal manures and incompletely composted materials used as fertilizers.
- Avoid wetting the leaves and fruits of plant when irrigating to minimize spread of disease
- Avoid over irrigation during the weeks before harvest (decrease produce firmness, increases storage problems)
- Practice field sanitation to prevent latent fungal infections and insect damage
- Use appropriate crop specific pest management practices (spray for insects or fungal control, insect traps etc)

10. General Dos and Don’ts for harvesting:

- Always consider the needs and requirements of the market for your produce (Buyer / Customer preference for size and / or stage of maturity)
- Regardless of commodity or development stage of produce, all horticultural products require extreme care at harvest
- Containers used for harvesting should be clean, smooth and free of rough edges, vented and not too large, steel or plastic buckets make good harvesting containers.
- Use stackable plastic crates as field containers during harvest – while initially expensive, these are durable, reusable and easily cleaned
- Train harvest personnel in the proper way to harvest the crop to minimize damage and waste during harvest
- Do not pick up produce that has fallen onto the ground during harvesting
- Train harvesters to recognize proper harvesting stage for the produce they are handling (Such as size shape, colour, firmness etc)
- Wearing cotton gloves, trimming fingernails and removing jewellery such as rings and bracelets can help reduce mechanical injury during harvest.
- Train pickers to empty their picking bags and / or baskets with care, never dumping or throwing produce into field containers
- Keep produce clean and free from soil contamination

- Avoid laying harvested produce on bare soil
- Always provide shade for harvested produce to prevent heat and sun damage
- Night or early morning harvest is sometimes an option for harvesting produce when internal temperatures are low. Let dew dry off first if harvesting crop is susceptible to fungal diseases.
- Cool produce as soon as possible after harvest
- Disinfect all tools and equipment's that comes in contact with produce
- Consider field packing to reduce the number of times produce is handled between harvest and marketing
- Cure root and tuber crops intended for storage by exposing them to moist, warm conditions that heal wounds and thicken peels.
- Cure bulb crops such as Onions and Garlic (by drying neck tissue and outer skins) before packing, storage and marketing

11. General Dos and Don'ts for packing

- Provide shade for harvested produce waiting to be sorted and packed
- Grade the roads and entryways between the field and pack house
- Avoid locating the pack house directly next to an unpaved, dusty road.
- Minimize mechanical damage-avoid drops, throwing, and rough handling
- Use hand carts to assist workers in the careful movement of produce
- Pre-sort to remove damaged, diseased, immature or over mature produce
- Provide good lighting to help sorters see defects
- Comfortable workstations will increase worker efficiency and help to reduce fatigue
- Keep the packing line as simple as possible and keep it clean. The packing line should be as straight as possible (avoid turns)
- Provide sanitary facilities (bathrooms and hand washing stations) for workers
- Provide clean and sanitary conditions for all supplies, including packing material storage
- Hand sorting can reduce damage if workers are well trained and provided with appropriate tools and equipment
- Know the requirements and postharvest handling recommendations for the crop you handle
- Consider the use of water dump system for handling water-tolerant produce
- Monitor pH levels (6.0 to 7.0) and chlorine levels (100 to 150 ppm) in wash water to ensure adequate levels.
- Provide cushioning on all sharp edges and rough surfaces of packing tables or the washing, sorting, grading, packing lines. Clean the tables regularly

- When trimming the produce do not remove more than necessary for high quality. Dispose-off waste materials properly.
- Use appropriate post-harvest treatments (waxing, hot water dips, SO_2, fungicides etc) to reduce the rate of decay or water loss
- Do not use any chemical treatments that are not specifically recommended or approved for your commodity.
- Pack securely to immobilize the produce, but do not overfill or under fill packages

12. General Dos and Don’ts for storage

- Store only high-quality produce, free of damage decay and of proper maturity
- Know the requirements for the commodity you want to put into storage and follow recommendations for proper temperature, relative humidity, and ventilation.
- Cure root, tuber and bulb crops before storage
- Avoid lower than recommended temperatures in storage-many commodities are susceptible to damage from freezing or chilling.
- Do not overload storage chambers or stack containers too close together. Leave about 5-10 cm between the stacks and the walls and place produce upon pallets
- Provide adequate ventilation in the storage room
- Containers must be well ventilated and strong enough to withstand stacking. Do NOT stack containers beyond their stacking strength
- Monitor temperature in the storage room by placing thermometers at a variety of locations
- Do not store Onion and Garlic in high humidity environments
- Avoid storing ethylene sensitive commodities with those that produce ethylene.
- Inspect stored produce regularly for signs of injury, water loss, damage and disease. Remove damaged or diseased produce to prevent the spread of problems.

13. General Dos and Don’ts for Transport

- Do NOT overload vehicles
- Prevent compression damage to produce by avoiding overfilling of containers and stacking heavier produce at the bottom of the load.
- Use strong packages
- Avoid rough handling during loading and unloading
- When stacking containers, be sure to align them properly (most of the strength of a corrugated box is in the corners) A one-inch overhang will decrease stacking strength by 15-34%
- Prevent vibration damage by using air suspension systems – these will provide a gentle ride during transportation.

- Using suitable trays, place packing, use of plastic bags, container liners, or placing a soft pad at the top of a full box can reduce vibration damage
- Make sure vehicle has adequate ventilation to prevent heat gain during transport

14. Handling protocol for selected fruits

14.1 Aonla (Emblica Officinalis Gaertn)



At Orchard:

Wild or planted throughout the deciduous forests of tropical India and on hill slopes. Fruits have lot of medicinal properties contain high amounts of ascorbic acid (vitamin C)

A light as well as medium heavy soil except purely sandy soil is ideal for Aonla cultivation. The tree is well adapted to dry regions and can also be grown in moderate alkaline soil.

It is a tropical plant. Annual rainfall of 630-800 mm is ideal for its growth. The young plant up to the age of 3 years should be protected from hot wind during May-June and from frost during winter months. The mature plants can tolerate freezing temperature as well as high temperature up to 46 degree Celsius.

The varieties recommended for cultivation are Banarasi, Chakaiya, Francis, NA-4 (Krishna), NA 5 (Kanchan), NA-6, NA-7, NA-10 and BSR-1 (Bhavanisagar).

Aonla is generally propagated by shield budding. Budding is done on one-year old seedlings with buds collected from superior varieties yielding big sized fruits. Older trees or poor yielder can be changed into superior types by top working.

The pits of 1-meter square are to be dug during May-June at a distance of 4.5 m spacing and should be left for 15-20 days exposing to sunlight.

Each pit should be filled with surface soil mixed with 15 kg farmyard manure and 0.5 kg of phosphorus before planting the budded seedling.

Leaving only 4-5 well shaped branches with wide angle at about 0.75 m from the ground level, other dead, diseased week crisscrossing branches and suckers should be pruned off at the end of December.

During summer, the crop should be mulched with paddy straw or wheat straw at the base of the tree up to 15-20 cm from the trunk. Inter crops like green gram, black gram, cow pea and horse gram can be grown up to 8 years.

Disease and Management

(a) Ring Rust or Aonla Rust (Ravenelia Emblicae)

Symptoms:

- Ring rust appears as circular or semi-circular, reddish solitary or greagarious spots on leaves from the beginning of August. Infection on fruits follow.
- Generally, one or two pustules measuring 10 to 20 mm in diameter appear on infected fruit.

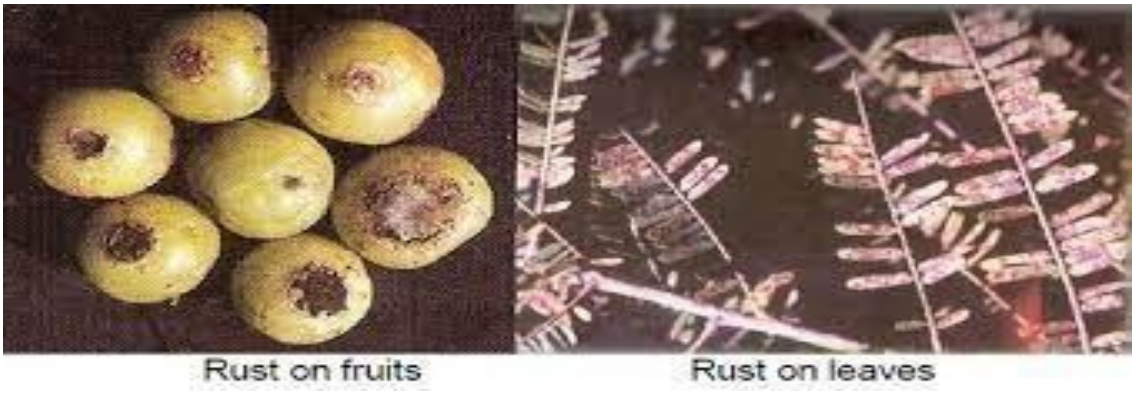


Figure. 63 Ring Rust

Management:

- Spraying with Dithane Z -78 at 0.2% at the interval of 7 to 28 days during the months of July to September proves effective.

(b) Fruit Rot (Penicillium oxalicum; P. islandicum):

Symptoms:

- The earliest symptom of infection is seen as water-soaked lesion on the fruit surface, which enlarges in size followed by development of small pin head size colonies of golden yellow colour. The older colonies turn olive green.

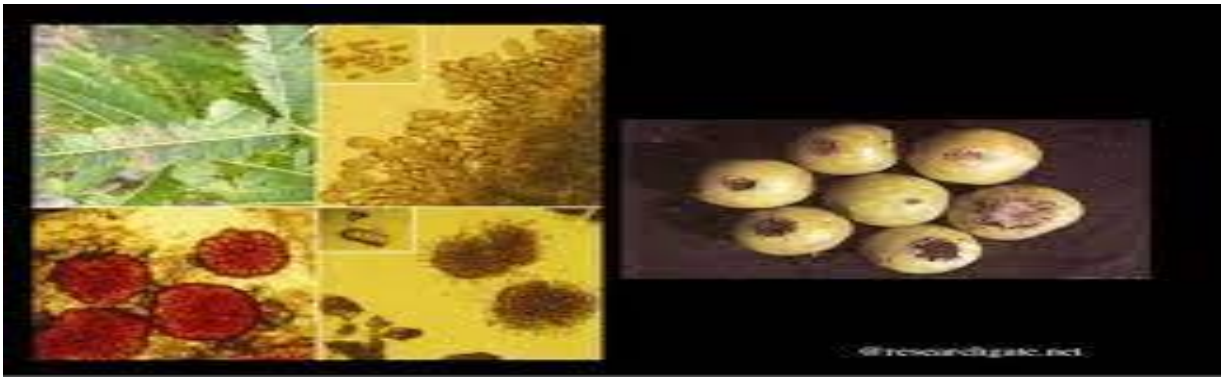


Figure.64 Fruit Rot Management

It is recommended that fruits showing such symptoms are discarded for marketing. Bruising and injury at the time of harvesting should be avoided. Treatment of fruits with borax and NaCl to control diseases.

Harvesting and yield:

Aonla tree starts bearing after about 4-5 years of planting.

The fruits are harvested when they become dull greenish yellow.

The change in seed colour from creamy white to brown is indicative of fruit maturity the mature fruits are hard, and they do not fall at gentle tough and therefore vigorous shaking is required.

Fruits can also be harvested using long bamboo poles attached with hooks.

A mature tree of about 10 years will yield 50-70 kg of fruit. The average weight of the fruit is 60-70 g and 1 kg contain about 15-20 fruits. A well-maintained tree *yields up to an age of 70 years.*

Figure 65: Aonla fruit on the plant.

Processing and Products:

Aonla is being processed and preserved in various forms such as Aonla Preserve (Murrabbas, Candy and Jams, Aonla Sauce, Juice and Pulp Preparation, Aonla Shred Drying and Powder Preparation, Dried Aonla shreds, Aonla Pickles etc.

Packaging:

Aonla fruits should be packed in perforated corrugated cartons with Newspaper lining

Storage:

Aonla fruits are highly perishable in nature as it`s storage in atmospheric conditions after harvesting is very limited. The fruits may be kept in cold storage for 7-8 days at 0-2°C and 85-90% relative humidity.

Transport:

Use tight packed transport to protect the fruits from vibratory damage to the fruit skin as it is highly susceptible to bruising.

14.2 Apple (Malus pumila)

Royal Delicious

Golden

Red Delicious

Apple (Malus pumila) is a climacteric fruit commercially grown in temperate regions of the world. Commercially the most important temperate fruit and is fourth among the most widely produced fruits after banana, orange, and grapes. It is mostly grown in the states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, and Nagaland.

Apple can be grown at altitudes 1,500-2,700 m. above mean sea level in the Himalayan range which experience 1,000-1,500 hours of chilling (the no. of hours during which temperature remains at or below 7deg C during the winter season). For optimum growth and fruiting, apple trees need 100-125 cm. of

annual rainfall, evenly distributed during the growing season. Excessive rains and fog near the fruit maturity period result in poor fruit quality with improper colour development and fungal spots on its surface. Areas exposed to high velocity of winds are not desirable for apple cultivation. Loamy soils rich in organic matter with pH 5.5 to 6.5 and having proper drainage and aeration are suitable for cultivation of Apples.

Use of growth hormones is essential for good flowering and proper colouration in fruits. Heavy bearing in apple usually results in small-sized, poor quality fruits and sets in alternate bearing cycle. Fruit thinning is essential in pollinating varieties for regulating adequate cross-pollination.

Disease and Management:

(a) Scab: Venturia inaequalis

Symptoms:

- Symptom appears on leaves and fruits.
- On lower side of the leaf lesion appear as olivaceous spots which turn dark brown to black and become velvety.
- On young foliage, the spots have a radiating appearance with a feathery edge.
- On older leaves the lesions are more definite in outline.
- The lesion may form a convex surface with corresponding concave area on the opposite side.
- In severe infection leaf blade curved, dwarfed, and distorted.
- Fruits show small, rough, black circular lesions.
- The centre of the spots become corky and on mature fruits, yellow halo is seen around the lesions.

Figure 66 Scab on apple

Management:

- Clean cultivation, collection, and destruction of fallen leaves and pruned materials in winter to prevent the sexual cycle.
- Spray Tridemorph 0.1% before flowering.
- Spray Mancozeb 0.25 % at bearing stage.

- Spray 5 % urea prior to leaf fall in autumn and 2 % before bud break to hasten the decomposition of leaves.

(b) Powdery mildew: Podosphaera leucotricha

Symptom:

- Small patches of white powdery growth appear on upper side of leaves.
- In severe case the symptom appears on both the sides.
- Twigs are also infected. Affected leaves fall off in severe infection.
- Fruit buds are also affected and deformed or remain small.

Figure 67 Powdery mildew

Management:

- Spray Dinocap 0.05% or Chinomethionate 0.1%

(c) Fire blight: Erwinia amylovora

Symptom:

- The initial symptom usually occurs on leaves, which become water soaked, then shrivel turn brownish to black in colour and fall or remain hanging in tree.
- The symptom spread to twigs. Terminal twigs wilt from tip to downward and also spread to branches.
- Fruits becomes water soaked, turns brown, shrivels, and finally becomes black.
- Oozing may be seen in the affected area.

Figure 68 Powdery mildew

Management

- Removal and destruction of affected parts.
- Removal of blighted twigs
- Spray with Streptomycin 500 ppm.

(d) Soft rot: Penicillium expansum

Symptom

- Young spots start from stem end of the fruit as light brown watery rot. As the fruit ripens area of the rotting increases,
- Skin becomes wrinkled.
- A peculiar musty odour is emitted
- Under humid condition a bluish green sporulating growth appears.
- Infection take place by wounds in the skin caused by insects and during handing in storage and transport.

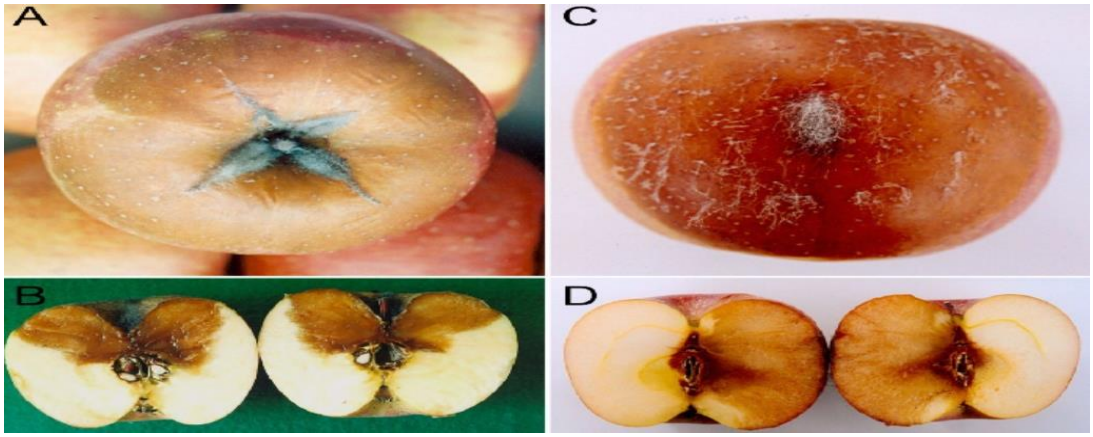


Figure 69 Soft Rot

Management

- Careful handling of fruits without causing any wounds.
- Dipping the fruits aureofunginsol @ 500 ppm for 20 min gives best control.

(e) Bitter rot: Glomerella cingulata

Symptom

- Faint, light brown discolouration beneath the skin develops. The discolouration expands in a cone shape. The circular, rough lesions become depressed. The lesions increased and covers entire areas of fruits.
- Diny black dots appear beneath the cuticle which gives rise to acervuli.
- Pink masses of spores are found arranged in defined rings.

Figure 70 Bitter rot

Management

- Spray Mancozeb 0.25 % in field.
- Treatment with Mancozeb 0.25 % to check the disease in storage.

POST HARVEST MANAGEMENT

Apple quality and its postharvest life can be influenced by several factors, including harvest maturity, storage conditions, and postharvest treatments. Apples have a relatively long storage life compared with other fruit crops. However, the main problem of apple storage is the decrease of fruit firmness. Fruit ripening is accompanied by softening, which is one of the most important determinants of fruit quality and consumer acceptability. Numerous techniques, including controlled atmosphere storage, modified atmosphere packaging, wax, coatings, etc., have been employed for increasing the shelf life of apple fruit.

Harvesting Maturity: The maturity at which Apples are harvested, greatly influences their ultimate quality. Harvest maturity controls the fruit's flavour components, physiological deterioration problems, susceptibility to mechanical injuries, resistance to moisture loss, susceptibility to invasion of rot organisms and ability to ripen. Criteria commonly used to check maturity of Apples are

Mean days Lapsed after full bloom – 110-120 days for red and royal, 145 days for golden

Surface Colour - 50 to >75%

Seed Colour – Brownish

Average starch iodine score - 4.5 to 5.5.

Fruit firmness (fruit pressure- 14-16 psi

Total soluble solids (TSS) – 10-12

Ease of fruit separation from spur – easily separated

Post-harvest Diseases and physiological disorders: Apples suffer storage loss from Botrytis and Penicillium rots which can develop in wounds or at the stem or calyx end.

Physiological dis-orders: A number of physiological disorders such as Storage scald Water core Bitter pit Bruising can cause serious loss, especially after prolonged storage

Harvesting: Fruits should be harvested very carefully to avoid any impact damage to the fruit surface. Smooth containers lined with cloth should be used to collect the harvested fruits. Harvested fruits shall be transferred to field containers in a gentle manner and should not be dropped from height. Should be kept is shade.

Field Sorting Grading: Grading of apples is done according to fruit size and fruit appearance or quality. On the basis of fruit size, apples are graded in following 7 grades. On the basis of fruit colour, shape, quality and appearance, apple fruits can be graded in three or more quality grades. These grades are designated as AAA, AA and A; A, B, C; grades. Harvested Apples should be sorted to remove diseased and defective fruits such as hailed ones, mis shape, insect infested, less colour etc. Sorted fruits should be size graded manually in the field or shall be taken to nearest pack house for sorting grading on the automatic s/g lines. Fruits should ideally be graded in to following grades:

Extra Large: 80 Counts – Diameter >80 mm

Large (100 counts) – Diameter >80 mm

Medium (125 counts) – Diameter 74-80 mm

Small (150 counts) - Diameter 66-73 mm

Extra Small (175 Counts) – Diameter 60-65 mm

Extra Extra Small – (200, 210 & 240 counts) 50-60 mm

Pitto (Packed loose with separators) - <50 mm

Figure 71: Apple segregation in the orchard.

Pre-cooling: In order to extend the storage life, Apples should be pre-cooled to remove the field heat immediately after harvesting as soon as possible

Wholesale Packaging: Size graded Apples should be packed in trays of specified sizes further packed in the 10 or 20 kg telescopic corrugated cartons. Cartons should be properly taped and stripped to avoid the vibratory movement of Apples inside. Over packing of apples should be avoided in the cartons. Cup size of the trays is designed according to the diameter of the Apples hence over size Apples should not be packed in the trays designated for lower size.

Figure 72: Apple wholesale packaging

Retail Packaging:

6 -12 Apples (1-2 kg) may be shrink packed in fibre or plastic trays or cardboard boxes, further packed in to corrugated cartons or plastic Crates for safe transportation to Retail outlets.

Figure 73 Apple retail packaging.

Storage: Apples have a long storage life compared to other fruits and can be stored for a period of 4-8 months after harvesting. The fruits can be kept in cold storage at a temperature of about 0-1 deg C and 85-90% relative humidity. Apples respond best to Controlled atmosphere (CA). In CA storage the composition of the air is modified inside the chamber by flushing of Nitrogen. Composition of air depends on the varieties stored. Indian Varieties such as Royal Delicious, Red Delicious, and Golden etc respond well to 1% Carbon Di Oxide and 3% Oxygen.

Transportation:

Road transport by trucks is the most popular mode of transport due to easy approach from orchards to the market. Pre-cooled Apples or Stored Apples should be transported in reefer trucks

14.3 Sapota (Chiku)

Sapota, popularly known in India as chiku, is native to tropical America, belongs to family Sapotaceae. Sapota being a tropical fruit crop can be grown from sea level upto 1200 M. It prefers a warm and moist weather and grows in both dry and humid areas. Coastal climate is the best suited. Areas with an annual rainfall of 1250-2500 mm are highly suitable. The optimum temperature is between 11°C and 34°C. Sapota being a hardy tree can be grown on a wide range of soils. Soil should be well drained without any hard pan. Deep and porous soils are preferred. The most ideal soils are deep alluvium, sandy loams, red laterites and medium black soil. It can tolerate the presence of salts in the soil and irrigation water to certain extent.

It is a tropical crop and can be grown up to an altitude of 1000 meters. It can be grown in all types of soils. The fruit is highly delicious, nutritive, and valued for its melting and sweet taste. It weighs about 70 to 300 g, has a dull brown color with thin skin with yellowish, light brown or red pulp. Raw sapota fruits

are astringent, while ripe fruits are sweet. Mature fruits are used for making mixed fruit jams and provide a valuable source of raw material for the manufacture of industrial glucose, pectin, and natural fruit jellies. Ripe fruits are eaten as dessert fruit and also are canned. The shelf life is very short about i.e., 3.5, 5.0, or 7.0 days after harvest when stored at 27, 25, or 319 20 °C, respectively. Sapota fruits are highly perishable due to their climacteric nature. Sapota is climacteric in nature and hence needs careful handling to minimize losses during its postharvest life for instance, juices, jam, jellies, and canned fruits stay for a longer period. This process not only enhances the life of perishable products but also creates a good market relative to that in raw form. It helps to withdraw the surplus produce from the market in the post-harvest season, stabilizes the prices and assists in maintaining a stock of fruits to meet the demand in off-seasons.

Disease and Management:

(a). Leaf spot: *Phaeoleospora indica*

Symptom:

- The disease is characterized by numerous, small, pinkish to reddish brown spots with whitish centres in the leaf.

Figure 74 Leaf spot

Management:

- Spray Mancozeb @ 0.25% or Copper oxychloride 0.2% to control the disease

(b). Sooty mould: Capnodium sp.

Symptom

- It is a fungal disease developed on honeydew-like excretion secreted by aphids and scale insects.
- The fungus slowly covers the entire leaf area severely affecting the process of photosynthesis.
- This results in reduced translocation of food to the fruits, which leads to reduction in their size.

Figure 75: Sooty mould

Management

- Spray starch solution 5% to remove the fungal growth.
- Control insects by spraying systemic insecticides.

Harvesting:

Sapota is climacteric fruit that requires careful handling after harvest in order to maintain quality, extend shelf life and allow transport to markets outside the area of production. Unlike many other fruits, sapota rarely exhibits any marked changes in external color or texture to indicate maturity . Hence, judging the maturity of sapota is comparatively skill oriented. In sapota two main seasons of flowering are October-November and February-March and the two corresponding harvesting seasons are January-February and May-June. Sapodilla trees may have harvestable fruits year-round, though there is a main season for each cultivar. The erratic flowering habit and the presence of fruits at all stages of development on the tree make it difficult to determine optimum harvest time . Fruit picked at optimum maturity usually ripen in 4 to 10 days depending on storage conditions. If the fruits are harvested earlier than physiological maturity may not soften, are usually low in sweetness, flavor and high in astringency when ripe due to pockets of coagulated latex within the flesh, with a rather unappealing alcoholic after taste, and form pockets of coagulated latex that lower the quality. Unripe fruit are highly astringent and contain large amounts of leuco anthocyanidins.

At maturity the fruit texture was smooth and flesh colour beneath skin was yellow and specific gravity reached to one. The flesh colour of fruit at maturity was brown in all the varieties and reddish brown in case of PKM-3.

Packing and grading:

Assembling in plastic crates/bamboo baskets/wooden boxes. Place harvested fruits into a clean and perforated plastic crates having foam sheet or newspapers as cushioning materials to reduce impact bruising. Fruit are commonly packed in fiberboard or wood flats.

Postharvest treatments:

Being climacteric in nature sapota is a quick ripening fruit. Therefore, to maintain the quality and to allow proper marketing, sapota needs adequate postharvest management technologies starting from

harvesting to ultimate consumer. A few postharvest treatments have been opined to increase the shelf life of sapota are Pre-cooling, Heat treatment, Cold Storage, Waxing/Coating, Modified atmosphere packaging (MAP) and Controlled atmospheric storage (CAS).

Value added products of sapota:

Sapota being a climacteric fruit, it undergoes rapid ripening changes within 5-7 days after harvesting, during which the fruit becomes soft, sweet, and develops excellent aroma with decline in tannins, latex sapotin, aldehydes and acidity. These changes are associated with increase in the activities of enzymes like catalase and peroxides. Owing to these rapid biochemical changes, the sapota fruits have very poor shelf-life as compared to many other climacteric fruits.

Under these circumstances, value addition through processing is important for economic utilization of increased production of sapota and conversion of fruits into suitable value-added products is the only alternative so that the farmers can get assured price for their produce all the time. Some of the value-added products are Sapota nectar, Sapota squash, Osmodehydrated sapota slices, Sapota jam, Sapota Butter, Sapota Cheese, Sapota Jelly, Sapota powder, Instant Sapota Milkshake Mix, Sapota wine preparation

14.4 Guava

Guava is a subtropical crop. It is one of the most common and major fruits of India and is considered the fourth most important fruit in area and production after mango, banana, and citrus. It is a hardy and prolific bearer and highly remunerative fruit. Guava is native to tropical America and seems to have been growing from Mexico to Peru. It is believed to be introduced in to India during early 17th century. In A.P it is commercially grown in Telengana, North coastal districts and Ananthapur in Rayalaseema. Guava is the rich source of Vitamin C, and a fair source of Vitamin A and B2 and minerals like calcium, phosphorus, and iron. The vitamin C content of Guava is 2-5 times higher than oranges.

Guava cultivation can be extended to varying agro-climatic regions owing to wider adaptability. Guava can be successfully cultivated both under tropical and subtropical conditions. It does well up to an altitude of 1,000-1,500 meters. It grows best with an annual rainfall below 100cm restricted between June-September. Places having more than 250cm rainfall are not suitable for guava. Optimum temperature requirement is 23-28 degree Celsius.

Guava adapts well to a wide range of soils. Well-drained, light sandy loam to clay soils is good. Since it is a hardy fruit crop, it can be grown on alkaline soils wastelands etc. It is sensitive to waterlogged conditions. It tolerates a wide range of pH from 4.5 to 8.5. If the soils are having a pH of 7.5 and above there are more chances of getting guava wilt. Some varieties like Lucknow- 49 can be grown in saline soils also.

Post–Harvest Management

Harvest stage depends on variety and the stage at which fruit are to be eaten. If eaten green, fruit should be harvested at the mature, firm stage without any signs of ripening. Fruit to be consumed soft and ripe are harvested when they show some sign of color change from green to yellow, as well as initial softening. Later harvesting, when fruit are riper, can lead to a high number of fruit fly stings and later larvae in the flesh. SSC can vary from 3% in green fruit to > 10% in ripe fruit, and the TA from 0.2 to 1.5%; cultivars vary greatly in sweetness and acidity. There is seasonal variation in acidity in some cultivars. Guava is climacteric in nature and should be picked when it is mature but firm. Picked at the right stage of maturity, fruits on ripening give excellent taste and flavour, characteristic of cultivar. The seedling if guava comes into bearing very late i.e., after 5–6 years of planting. However, the grafted or air–layered plants are precocious in bearing and first crop appears at the age of 2 to 3 years. Individual fruits are picked when they are still hard and firm at regular intervals.

Packaging:

The fruits should preferably be packed in corrugated fiber board cartons of sizes ranging from 4–10 kg or in bamboo baskets of different sizes. Positioning of guava fruit in the natural posture with pedicel end vertically upward may result in better keeping quality as compared with fruits kept in reverse or horizontal position. For local markets the fruits are packed in bamboo baskets. As padding material neem leaves or dried grass is used.

Optimum Storage Conditions

Mature green and partially ripe fruit can be held for 2 to 3 weeks at 8 to 10°C (46 to 50°F). Ripe, soft fruit can be held about 1 week at 5 to 8°C (41 to 46°F) temperature and 90 to 95% relative humidity. Shelf–life is about 7 days when stored at 20°C (68°F).

Value added Products:

Jelly, jam, pulp concentrate, juice, cheese, toffee, dehydrated and canned guavas are some conventional products which can be made from fresh guava fruit thus, reducing the post-harvest losses. CISH, Lucknow has developed cider, probiotic guava drink, vinegar, beverages, soup, ketchup etc, from guava. Functional food ingredient including pectin, dietary fiber, lycopene were extracted from pink guava fruits

14.5 Banana



Banana is a globally important fruit crop with 97.5 million tons of production. In India Banana contributes 37% to total fruit production in India. It occupies 20% of the total area under crop in India. Maharashtra ranks second in area and first in productivity. Jalgaon is a major Banana growing district in Maharashtra which occupies 50,000 hectares area under Banana. But most of Banana is grown by planting suckers. The technology development in agriculture is very fast, it results in developing Tissue Culture Technique.

Banana is basically a tropical crop, grows well in temperature range of 13ºC – 38ºC with RH regime of 75-85%. Chilling injury occurs at temperatures below 12ºC. The normal growth of the banana begins at 18ºC, reaches optimum at 27ºC, then declines and comes to a halt at 38ºC.

Soil for banana should have good drainage, adequate fertility and moisture. Deep, rich loamy soil with pH between 6-7.5 are most preferred for banana cultivation.

Around 20 cultivars viz. Dwarf Cavendish, Robusta, Monthan, Poovan, Nendran, Red banana, Nyali, Safed Velchi, Basarai, Ardhapuri, Rasthali, Karpurvalli, Karthali and Grandnaine etc. are being grown in India.

Traditionally banana growers plant the crop at 1.5m x 1.5m with high density, however plant growth and yields are best at a spacing of 1.82m x 1.52m, it accommodates 1452 plants per acre. The region like north India, coastal belt and where humidity is very high and temp falls up to 5-7ºC, the planting distance should not be less than 2.1m x 1.5m.

Polybags is separated from the plant without disturbing the root ball of the plant and then plants are planted in the pits keeping the pseudo-stem 2cm below the ground level. Soil around the plant is gently pressed. Deep planting should be avoided.

Banana, a water loving plant, requires a large quantity of water for maximum productivity. But Banana roots are poor withdrawal of water. Therefore, under Indian condition banana production should be supported by an efficient irrigation system like drip irrigation.

Banana requires high amount of nutrients, which are often supplied only in part by the soil. Nutrient requirement has been worked out on all India basis is to be 20 kg FYM, 200gm N; 60-70gm P; 300gm K /plant.

Spraying of Glyphosate (Round up) before planting at the rate of 2 lit/ha is carried out to keep the plantation weed free. One or two manual weeding are necessary.

Removal of unwanted suckers is a critical operation in banana for reducing internal competition with mother plant. Desuckering should be done regularly until shooting. However, in areas where ratoon is also taken for the second crop, a follower is allowed after inflorescence has appeared and this should be managed that planting space is not disturbed. Follower should be opposite to the inflorescence. It should not be far apart from the main plant.

It consists of removal of the withered style and perianth. This is generally not practiced. Therefore, they remain attached to the fruit bunch & then removed after harvesting which is damaging to the fruits. It is therefore suggested that they should be removed just after flowering.

Rubbing leaves damages the fruit, therefore, such leaves should also be pruned during regular check. Older leaves and infected leaves also be pruned as required. Green leaves should not be removed.

Keep the soil loose by harrowing from time to time. Earthing up should be done at 3-4 months after planting i.e. raising the soil level around the base of the plant by 10-12". It is better to prepare a raised bed and keep the drip line on bed 2-3" away from the plant. It also helps to protect plants from wind damage and production losses to some extent.

(Denavelling) Removal of male buds helps fruit development and increases bunch weight. Male buds are removed from the last 1-2 small hands with a clean cut keeping a single finger in the last hand.

Spray of monographs (0.2%) after emergence of all hands takes care of the thrips. Thrips attack discolors the fruit skin and makes it unattractive.

Covering bunch using dried leaves of the plant is economical and prevents the bunch from direct exposure to sunlight. Bunch cover enhances quality of fruit. But in rainy season this practice should be

avoided. Sleeving of bunch is done to protect fruits against dust, spray residue, insect and birds. For this blue plastic sleeves are preferred. This also increases temperature around developing bunch and helps in early maturity.

In a bunch there are some incomplete hands which are not fit for quality produce. These hands should be removed soon after bloom. This helps in improving the weight of other hands. Sometimes the hand just above the false hand is also removed.

Due to heavy weight of bunch the plant goes out of balance and the bearing plant may lodge and production and quality are adversely affected. Therefore, they should be propped with the help of two bamboos forming a triangle by placing them against the stems on the leaning side. This also helps in uniform development of bunch.

A large number of fungal, viral and bacterial diseases and insect pests and nematodes infest the banana crop and reduce production, productivity and quality. Hence proper disease management is a must.

Disease and Management:

(a) Anthracnose: Gloeosporium musarum

Symptom:

- At the initial stage, small, circular, black spots develop on the affected fruits. Then these spots enlarge in size, turn to brown colour.
- The skin of the fruit turns black and shrivels and becomes covered with characteristic pink acervuli. Finally, the whole finger is affected. Later the disease spreads and affects the whole bunch.
- The disease results in premature ripening and shriveling of the fruits which are covered with pink spore masses.
- Occurrence of black lesions on the pedicel causes withering of the pedicel and dropping of the fingers from the hands
- Sometimes the main stalk of the bunch may become diseased. Infected fruits become black and rotten
- The disease is favoured by high atmospheric temperature and humidity, wounds and brusies caused in the fruit and susceptibility of the variety

Figure 76 Anthracnose

Management:

- Avoid damage to fruits at harvest and transit
- Burn the infected materials
- Proper field sanitation
- Keep the field free of weeds and provide good drainage
- Fruit should be free from infection and as possible before it is transported, stored and ripened
- Banana bunches should be harvested at correct stage of maturity.
- Proper fertilization prevents the infection

(b) Bunchy Top: Banana bunchy top virus

Symptom:

- Initially, dark green streaks appear in the veins of lower portion of the leaf midrib and the leaf stem
- They appear to be “bunched” at the top of the plant, the symptom for which this disease is named.
- Severely infected banana plants usually will not fruit, but if fruit is produced, the banana hands and fingers are likely to be distorted and twisted.
- It is transmitted by infected suckers and banana aphid.

Figure 77 Bunchy Top

Management

- Use virus free planting materials
- Remove and rouging of infected banana plants
- Maintain clean, weed free field for early detection of infested suckers
- The plants should be injected with 4 ml of Fernoxone solution (50g in 400 ml of water)

- For vector controls Injection of plants with monocrotophos 4 ml (1:4) at 45 days interval from 3rd month till flowering
- Spraying plants with phosphomidon 1ml /l or Methyldemeton 2ml/ l or monocrotophos 1ml /l

Harvesting:

Banana should be harvested at the physiological maturity stage for better post-harvest quality. The fruit is climacteric and can reach consumption stage after ripening operation.

Maturity indices:

These are established on the basis of fruit shape, angularity, grade or diameter of the median figure of the second hand, starch content and number of days that have elapsed after flowering. Market preferences can also affect the decision for harvesting a slight or full mature fruit.

Removal of bunch:

Bunch should be harvested when figures of second hand from top are 3/4 rounded with the help of sharp sickle 30cm above the first hand. Harvest may be delayed up to 100-110 days after opening of the first hand. Harvested bunch should generally be collected in well-padded tray or basket and brought to the collection site. Bunches should be kept out of light after harvest, since this hastens ripening and softening. For local consumption, hands are often left on stalks and sold to retailers. For export, hands are cut into units of 4-16 fingers, graded for both length and girth, and carefully placed in poly-lined boxes to hold different weight depending on export requirements.

Post-harvest operations:

At collection site injured and over mature fruits shall be discarded and for local market bunches should be delivered through lorries or wagons. However, for more sophisticated and export market where the quality is predominant, bunches should be de-handed, fruits are cleared in running water or dilute sodium hypochlorite solution to remove the latex and treated with thiobendasole; air dried and graded on the basis of size of fingers as already stated, packed in ventilated CFB boxes of 14.5 kg capacity or as per requirement with polythene lining and pre-cooled at 13-15ºC temperature and 80-90% RH.Such material should than be sent under cool chain at 13ºC for marketing

Figure 78: Banana harvesting

Harvesting method:

The method of harvesting will depend on the height of the plant. Low-growing varieties can be harvested by cutting through the bunch stalk about 30 to 35 cm above the top hand. With taller varieties, the stem of the plant will be partly cut through to bring the bunch down within the harvester's reach, and then the bunch stalk can be cut through. Harvested bunches are best carried on a foam-padded tray to reduce damage during carrying.

Grading:

Grade Designation	Grade Requirement
Extra class	Bananas shall be of superior quality. They must be characteristics of the variety and/or commercial type. The fingers must be free of defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, quality, the keeping quality and presentation in the package.
Class 1	Bananas shall be of good quality. They must be characteristics of the variety and/or commercial type. The slight defects (as listed below) of the fingers, however, may be allowed, provided these do not affect the general appearance and quality of the produce in the package. - slight defects in shape and colour; - slight defects due to rubbing and other superficial defects not exceeding 2 sq.cm. of the total surface area, the defects must not affect the flesh of the fruit.
Class 2	This includes bananas which do not qualify for inclusion in the higher classes but satisfy the minimum requirements. The following defects may be there provided the bananas retain their essential characteristics with respect to the quality and presentation. - defects in shape and colour provided the product remains the normal characteristics of bananas; - skin defects due to scrapping, scabs, rubbing, blemishes or other causes not exceeding 4 sq.cm. of the total surface area; The defects must not affect the flesh of the fruit.

Packing.

All harvested bananas should be kept dry and in the shade before and after packing. Packing is best done in or as near to the field as possible. There must be facilities for keeping the fruit and packaging dry. As soon as the hands of bananas are cut from the stem, they should be laid, curved side uppermost, across the midribs of fresh banana leaves. This will prevent latex from the cut crown contaminating the fruit. Latex flow should stop in 12-15 minutes, after which the banana may be packed into wooden or, preferably, cardboard boxes, which can be of the slotted or telescopic type. Whole hands of bananas can be divided into clusters of four or more fruit which can be packed more compactly to give a greater weight of fruit per box. The hands or clusters should be packed in the boxes with the curved side uppermost, making sure that the crowns of the upper hands do not damage the bananas underneath.

Boxes should be full but not over-packed, otherwise the bananas will be damaged because the fruit itself and not the walls of the boxes will be supporting the upper boxes of the stack.

Figure 79 Banana packing and retail sell display.

Storage:

Bananas have a very short post-harvest life at ambient conditions.

This is four to ten days when mature green and two to four days when ripe.

Both green and ripe bananas are sensitive to cold and are damaged by temperatures less than 13^0 Celsius.

14.6 Cashew Nut

Cashew Fruit

Cashew Nuts

Cashew nuts may be cultivated for both the nut and apple. The cashew tree comes into bearing 3 to 5 years after planting. The fruit matures in 90 to 100 days after flowering. The ripe fruits normally start to drop in late January. The peak fruit collection period is between February and March, with a few late maturing trees dropping their fruits in April. It is important to remember that the excellence and thoroughness of post-harvest handling affects the quality of the product. Product quality influences the demand for those products on the whole market, which in turn positively affects the price.

Disease and Management:

(a) Die – back or Pink disease: Corticium salmonicolor

Symptoms:

- It is a very common disease of cashew, often assuming great importance during the south-west monsoon period
- Whitish or pinkish growth of the fungus can be seen on the affected branches.
- The fungus penetrates into the deeper tissues and causes the death of the shoots from the tip downwards and hence the name dieback.
- After heavy rains a film of silky thread of the fungus is seen on the branches.
- In advanced stages, the bark splits and peels off. Sometimes only one branch is affected, but often many branches turn yellow and shed giving a barren appearance to a portion of the tree.

Figure 80 Pink disease

Management:

- Prune the affected branches well below the site of infection and destroy them.
- Protect the cut surfaces by applying Bordeaux paste.
- If disease is severe, it is advisable to spray Bordeaux mixture (I %).
- Spraying is to be done twice, once in. May-June and the second during October.
- Collect all dried up and affected branches to reduce the source of inoculum.

(b) Shoot rot and leaf fall: *P. nicotianae* **var.** *nicotianae*

Symptoms:

- During the south west monsoon months of June - August extensive leaf fall and shoot rot symptoms are observed.
- Black elongate lesions are first developed on the stem with exudation of gum. Later, infection spreads up and down, causing the tender stem to collapse and tender leaves to shrivel up.

- The lower mature leaves are also infected with black elongated lesions on mid rib, which later spread to the main lateral veins and the leaf blade.
- The infected leaves are soon shed.

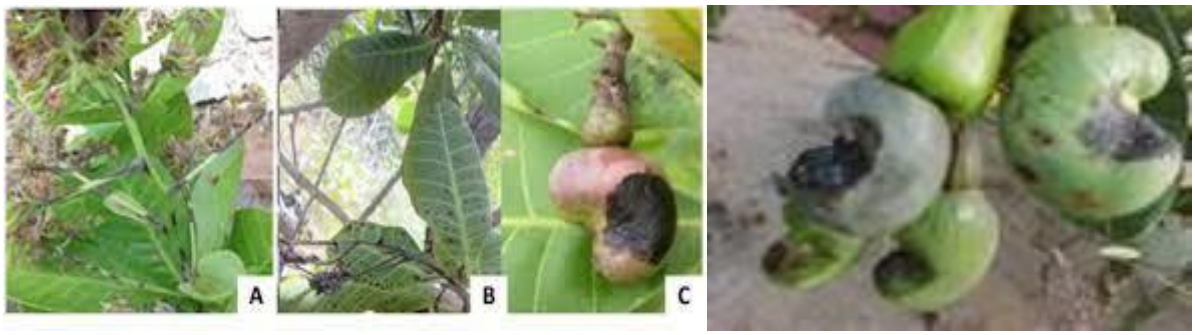


Figure 81 Shoot rot

Management:

- Spraying with Bordeaux mixture (l%) before the onset of monsoon will check the spread of the disease.

Before harvesting

It is important to weed the area under the trees clean, ahead of harvesting. This will facilitate the picking of fruits (apples and nuts).

Nut harvesting

Allow fruits to drop to the ground before picking. Fruits could be collected daily or at least every other day. Leaving the nuts uncollected on hotter days lowers the quality.

Figure 82 Separating cashew apple and nut

Handling of nuts

Neatly detach the apple completely from the nut, using a nylon thread or sharp knife. The quality of the nut is affected when the apple is not neatly detached from the nut. Air-dry collected nuts on concrete

floors, drying mats or tarpaulins under shade for3 to 4 days. Turn nuts frequently during the drying period to ensure uniform drying. Avoid drying indoors, or on metallic surfaces or directly in scorching sun since the quality of the nuts will deteriorate. Well-dried nuts produce a rattling sound when turned on the drying floor. Remove and discard immature, diseased, shriveled and damaged nuts along with any foreign matter when drying.


Figure 83: Sorting and grading of cashew nuts.

Storage of nuts

Store well-dried nuts in jute sacks, (no plastic or fertilizer sacks containers like boxes, buckets, etc.). Stitch jute sacks tightly to avoid spillage. Place the jute sacks on wooden pallets in a dry, well-ventilated leak proof room. Leave a clearance of at least 0.5 m between the packed jute sacks and the roof as well as between sacks and walls of the storage room to allow air to circulate freely. Sell nuts within the same year of harvest to prevent loss in quantity.

14.7 Citrus




Mosambi Oranges Lemon Kinnow

Harvesting:

Harvesting maturity. The assessment of the readiness of citrus fruit for harvest presents some problems for small-scale producers because:

- citrus fruits do not ripen further after harvest. To reach their full flavor and sweetness they must be left on the tree to ripen.
- in the tropics citrus often remain green when they are fully ripe internally and do not develop an orange yellow color on the tree. The development of the orange-yellow skin color can be artificially induced after harvest (de-greening). These facts make it very difficult to assess harvest maturity just from the appearance of the fruit on the tree. Small-scale producers marketing their own fruit will be able to assess the readiness of their fruit on several counts, which will vary in different situations, for example:
- Skin color: where it develops normally, this will be a good guide to ripeness; if normal skin color does not develop, maturity may be indicated by a change in the shade of green shown by the skin; lemons change from dark green to a silvery-green appearance at maturity.
- Size: experienced growers may evaluate maturity by considering size as well as with other characteristics, such as slight changes in skin color; and
- Internal condition of fruit: if a few typical fruits thought to be mature are cut in two, they can be considered ripe if:

1. The juice has developed full flavor and is sweet.

2. The fruit pulp has developed to the normal color; and

3. Juice drips from the half-fruit when the cut surface is held vertically.

Figure 84 Harvesting of Citrus

Disease and Management:

(a) Scab/Verucosis: Elsinoe fawcetti

Symptoms:

- Attacks leaves, twigs and fruits of mandarin.
- Sour orange, lemon, mandarin, tangelos extremely susceptible Grapefruit, sweet oranges and acid lime highly resistant. Severe in rainy seasons.
- On the leaves the disease starts as small pale orange coloured spots.
- The leaf tissue is distorted to firm hollow conical growths with the lesion at the apex.
- The crest of these growth becomes covered with scabby corky tissue colour at first but later becomes dark olive with age.

- Lesions most common on undersurface of leaf. They penetrate leaf and are later visible on both sides.
- infected areas run together and cover large area.Leaves wrinkled, distorted and stunted.
- On twigs similar lesions are produced.
- They form corky outgrowths.On fruits irregular scably spots or caked masses produced.
- Cream colour in young fruits; dark olive grey in old fruits.
- Fruits attacked when young become misshapen with prominent warty projections. They drop prematurely.

Figure 85 Scab

Management

- Spray Carbendazim 0.1%

(b) Canker: Xanthomonas campestris pv citri

Symptoms:

- Acid lime, lemon and grapefruit are affected. Rare on sweet oranges and mandarins.
- Affects leaf, twig and fruits. In canker, leaves are not distorted.
- Lesions are typically circular with yellow halo; appear on both sides of leaf, severe in acid lime (difference from scab) When lesions are produced on twigs, they are girdled and die.
- On fruits, canker lesions reduce market value.

Figure 86 Canker

Management

- Streptomycin sulphate 500-1000 ppm; or Phytomycin 2500 ppm or Copper oxychloride 0.2% at fortnight intervals.
- Control leaf miner when young flush is produced.

Prune badly infected twigs before the onset of monsoon

Harvesting method:

Although the skin of citrus fruit is relatively tough and can tolerate some degree of pressure, it is easily cut or punctured, providing access to the serious post-harvest decay diseases: blue and green moulds. Every care must always be taken to avoid cutting or puncturing the skin of citrus fruits. Clippers or secateurs should be used to remove the fruit from the tree. Fruit may be pulled by hand, but there is danger that the stem may be pulled out of the fruit, damaging the skin, or of damage to the tree providing an entry point for field diseases.

Not more than 0.5 cm of stem should be left attached to the fruit. If the fruit is mature or ripe this piece of stem will dry up and fall off, leaving only the flower calyx (button) attached to the fruit.

As it is harvested, citrus fruit should be placed in picking bags worn by the harvester or in plastic buckets.

Field handling:

Harvested fruit is taken in the harvesting container either directly to the packing facility or to the field assembly point, where it is emptied into field containers. At either point the fruit should be protected from exposure to sunlight and rain while awaiting packing or movement to the packing house.

Figure 87: Field assembly of citrus.

Post-harvest:

Selection: Before it is packed the fruit should be sorted to eliminate all foreign material, such as leaves and twigs. The fruit is then inspected and pieces which are unripe, immature, undersized, damaged or decaying should be discarded. The extent to which superficial skin damage can be tolerated will depend upon the market. Local consumers may be more concerned about the eating quality of produce than its external appearance.

Size grading Where citrus fruits are to be pattern-packed in custom-made cardboard boxes it is usually an advantage to grading it into size categories. The differences between categories will depend on the type of fruit. Suggested minimum sizes and grade category differences for different commodities are:

Commodity	Minimum (mm)	Grade difference (mm)
Oranges, lemons, mandarins	50	5-10.
Grapefruit	70	15-20.

Limes are not normally size-graded. Citrus sent to local markets in wooden crates will usually be size graded by the retailer at the point of sale.


Figure 88 Grading of citrus

Packing.

Citrus for sale in local and internal urban markets is packed in a variety of containers.

Baskets, wooden boxes, sacks, bags, factory-made wooden crates and cardboard boxes are all used.

Most citrus from large scale commercial production are now packed in telescopic cardboard boxes.

The recommended outside dimensions for the boxes are 50x 30x 30 cm. These can be stacked eight boxes per layer on standard 1 x 1.2 m pallets. The capacity of these boxes is about 18-20 kg.

Wooden crates can also be used for citrus provided they do not have sharp edges or splinters which will damage the skin of the fruit. Wooden crates should not exceed 25 kg capacity. Larger crates are difficult to handle and if dropped can severely damage the contents.

Citrus fruits can be packed a little above the top of the box so that they are under slight pressure when the box is closed. This prevents movement of fruit within the box during transport and handling and allows for natural shrinkage.


Figure 89 Citrus in plastic net bag for retail sell.

Post-harvest treatments.

Citrus produced for local and other internal markets should not require specific post-harvest treatments provided it is handled carefully and packed properly.

Commercially grown citrus for export is normally washed, treated with fungicide and wax-coated on highly automated packing lines.

There may be occasions where citrus for internal urban markets requires fungicide treatment. Where this is necessary, the fruit should be washed and dried after sorting, then treated with fungicide and dried before packing.

In those countries where some types of citrus remain green when ripe it is not usually necessary to de-green them for market. De-greening will only change the color of the skin of citrus fruits. It will not ripen them internally. De-greening is carried out by exposing the fruit to ethylene gas under controlled environmental conditions.

It can only add to the cost of the fruit to the consumer, without any compensation in eating quality. However, we are aware that most consumers purchase with the eyes, therefore yellow/orange color is preferable to the green one.

Storage

Citrus fruits can be held up to three weeks under ambient conditions, depending upon the temperature and moisture content of the air. In dry air they may lose moisture and shrink after a few days. Damaged fruit may become infected and decay quickly after harvest. Depending on the variety citrus can be stored in refrigerated rooms as follows:

• Grapefruits: at 10 to 15^0 C,85-90% Relative Humidity, for 6 to 8 weeks.

• Lemons: at 10 to 13^0 C, 85-90% Relative Humidity, for 1-6 months.

• Limes: at 9 to 10^0 C, 90-9656% Relative Humidity, for 6 to 8 weeks.

• Oranges: at 0 to 9^0 C, 90-95% Relative Humidity, for 3 to 8 weeks.

14.8 Litchi

Litchi (Litchi chinensis Sonn) is an important subtropical fruit crop of the country due to its high demand in the season and export potentiality. Cultivation of litchi is widely spread in eastern India covering approx. 100 km width from foothills of Himalaya from Bengal to Punjab. In India, the bulk of the litchi growing area lies in Bihar; other areas are sub-mountain tracts of Uttar Pradesh, Uttarakhand, West Bengal, Punjab, Assam, Tripura, and Odisha.

The important varieties grown are India are Shahi, China, Bedana, Rose Scented, Bombai, Purbi, Saharanpur, Muzaffarpur, and Kasba. Bihar is the premier state in litchi production and marketing.

The harvesting of litchi fruits starts from last week of April in Tripura to end of July in Himachal Pradesh and foothills of Uttarakhand. In Bihar, the harvesting period lies between 2nd week of May to 3rd week of June for different cultivars.

The ideal soil for litchi cultivation is deep well- drained loam soil rich in organic matter. The water table should be at least 1.25 m deep. It cannot stand waterlogging for long. Litchi prefers slightly acidic to neutral soil. The trees grow best in a pH range of 6.0 to 6.5.

Litchi prefers moist subtropical climate. Winter frost and dry heat in summer considerably damage the growth of the plants.

Litchi is commercially propagated through vegetative method. The plants raised from seed have slow growth, long juvenile period (8-12 years) and do not produce true-to-type fruit.

Litchi plant starts bearing after 5-6 years and attains commercial production stage after 10-12 years. The performance of orchard depends upon the proper layout, pit preparation, planting system, care and maintenance of young and bearing trees. Scientific management of the orchard including water and nutrient management, stature and canopy management of plants, pruning, treatment of shoots for flowering and fruiting and use of plant growth regulators to optimize the quality production.

Optimum soil moisture and humid microclimate in the orchard is of utmost importance for growth development and fruit production in Evergreen litchi plants.

Disease and Management

(a) Leaf Blight

Symptoms:

- A prominent disease in litchi nursery, also cause blight of panicles and developing fruits. The symptoms start from tip of the leaf as light brown to dark brown necrosis that advances towards both the margins of the leaf leading to complete necrosis of the affected leaves that dries up subsequently.

Figure 90 Leaf Blight

Management:

- Fungicidal spray of Copper oxychloride (0.25%) or Thiophanate methyl (0.15%) Chlorothalonil (0.15%) or Difenconazole (0.05%) can be done if disease severity increases.

(b) Twig Blight

Symptoms:

- Death of leaves on new shoots, and a foliar blight and tip dieback. The afflicted leaves give the impression as if they were scorched by the sun.

Figure 91 Twig Blight

Management:

- Fungicidal spray of Copper oxychloride (0.25%) or Carbendazim (0.1%) can be done if disease severity increases.

Post-Harvest Management:

Harvest Maturity: Litchi is a non-climacteric fruit and therefore it is advantageous to pick fruit soon after it reaches maturity. If picked immature, fruits develop lower amounts of Brix, acid ratio, taste and flavour, whereas over-mature fruits lose their storage life. It is, therefore, desirable to pick the fruits at the correct stage of maturity to facilitate ripening, distant transportation and maximum storage life.

Maturity Indices: Since the fruit is non climacteric and maturation virtually stops as soon as it is harvested. Following criteria may be followed to ascertain the litchi maturity.

Skin colour is usually a determinant of ripeness. The fruit is ready for harvesting when the pericarp is a uniform red, (just when the orange colour has disappeared completely or almost completely) Another useful test of ripeness is to check the colour of the inner surface of the skin, which should also be red.

Harvesting: Litchis shall be harvested carefully with stalk. Pedicel must be cut at the first knot and the maximum length of the stalk must not extend more than 2 mm beyond the top of the fruit presented if intended to be sold individually. If Fruit is to be marketed in bunches, the bunch must include more than three attached and well-formed litchis. The branch must not exceed 15 cm in length.

Pre-cooling: To remove the field heat litchi fruit should be hydro-cooled or air-cooled immediately after harvesting as soon as possible. Litchi must be pre-cooled to 5 deg C before storage,

Cooling speed is generally greater in hydro-cooling system without dehydration than air-cooling. When hydro-cooled, the internal temperature of the fruit is reduced to 5 deg C within 18 minutes, whereas air-cooling takes longer time. Hydro-cooled fruits packed in polyethylene lined boxes remain fresh and give the best appearance after 6 days of storage at 5 deg C.

Handling after Harvesting: Once harvested, exposure of litchi fruits to the sun and air can increase water loss by many folds. Therefore, harvested fruits should be kept at cooler place in the orchard or in temporary thatched house for cooling. The transfer of fruit to the pack house soon after harvest minimizes the opportunity for water loss in the field. Sorting of produce can be done during the harvest operation itself. Fruit with pulled stems, splits, cracks, insect damage, Scarred, cracked, discoloured or otherwise affected fruits can be placed in separate harvest containers or discarded completely and removed from the field later.

Precise operations such as washing and grading according to critical size, colour, etc may be better performed in a pack house. Field assembly should be planned bearing in mind the best location and the provision of basic facilities.

After harvesting, fruit should be packed as quickly as possible, as their quality deteriorates markedly if they are exposed to sun even for a few hours. Litchi can be packed in bunches, or as individual fruit. Fruit are often sold on panicles in India, whereas loose fruit are preferred for exports.

Browning in litchi fruit occurs within 24 hours at ambient temperatures of 20-30 deg C due to enzyme activity, probably an aerobic system of oxidative poly phenolase which is accelerated by drying. Two

conditions, humidity and low temperatures are vital to prevent darkening and to preserve the taste qualities of the fruit.

Packing for wholesale: Litchi may be packed in plastic crates with polythene liners or cardboard boxes, which provide better control of water loss.

A good box for packing fruits should be light in weight, shallow and rigid enough to protect the fruits. It should have few holes for ventilation and rope handles on either side for lifting the box. Fruits should be packed in clusters along with few leaves.

Figure 92 Wholesale packaging materials for Litchi.

Packing for Retail: For retails individual litchis can be packed in half Kg to 1 kg poly bags. Or plastic punnets. Litchis with stalk are sold in bunches.

Figure 93 Litchi retail packaging.

Storage: Litchi fruit cannot be kept for more than a few days after harvest, at room temperature. If marketing is delayed, fruits should be kept in cold storage to avoid rapid loss of colour and quality. Pre-cooling of fruits should be done before cold storage because without pre-cooling, browning could be more rapid compared to the storage of pre-cooled fruits at 2-5 deg C.

The cold storage without pre-cooling and chemical treatment has less impact on colour maintenance. Pre-cooling as well as chemical treatment has recorded shelf life up to 27 days at 5 deg C. Fruits treated with 2% sodium hypochlorite can be stored satisfactorily in perforated polythene bags at 0-3 deg C for 25 days. For short-term storage less than two weeks, a temperature of 7°C is satisfactory. A relative humidity should be kept at 90-95% throughout storage and transport.

Transport: Transporting the fruit dry and fairly tightly packed reduces the risk of vibration damage. Pre-cooled or stored litchis should be transported in reefer vans at 5 deg C temperature.

14.9 Mangoes

Mango Sinduri

Mango Safeda

Mango Dushehari

Mango Chausa

Mango Langra

Mango Alphonso

At Orchard:

Pre harvest survey:

An orchard survey must be undertaken to determine the right stage of harvest of fruit for export. Mangoes normally take 120-150 days from fruit set to maturity. Internally the fruit should have light yellow tinges to the flesh and slightly more yellow coloration round the stone. Fruit should be firm but not hard.

Harvesting:

Pick only clean and healthy-looking fruit i.e. no signs of damage by insect pests or diseases or by other means. All fruit must be of consistent maturity. Fruits should be harvested leaving 10 cm of stalk using mango harvesters and a smooth net pouch for holding the harvested fruit. Harvested fruit should be lowered and placed with stem upwards in clean and disinfected plastic crates. Crates should not be placed directly on the soil. Each crate should be labeled indicating the orchard name, variety date and time of harvesting.

Indian-Varieties

There are nearly 1000 mango varieties in India. However, only about 20 varieties are grown

commercially. Most of the Indian mango varieties have specific ecogeographical requirements for optimum growth and fruiting. Dashehari, Langra, Chausa, Bombay Green and Fazri in north India; Banganapalli, Totapuri, Neelum, Pairi, Suvarnarekha, Mulgoa, Kalapadi and Rumani in south India; Alphonso, Kesar, Mankurad, Fernandin' and 'Vanraj' in western India and 'Langra', 'Fazri; 'Chausa', 'Zardalu', 'Himsagar' and 'Malda' in eastern India are grown commercially. Brief characteristics of these varieties are given below.

Commercial-Varieties

Characteristics of important commercial mango varieties are as under:

1. **Alphonso**: This is the leading commercial variety of Maharashtra state and one of the choicest varieties of the country. This variety is known by different names in different regions, viz. Badami, Gundu, Khader, Appas, Happus and Kagdi Happus. The fruit of this variety is medium in size, ovate oblique in shape and orange yellow in colour. The fruit quality is excellent and keeping quality is good. It has been found good for canning purpose. It is mainly exported as fresh fruit to other countries. It is a mid-season variety.
2. **Bangalora** : It is a commercial variety of south India. The common synonyms of this variety are Totapuri, Kallamai, Thevadiyamuthi, Collector, Sundersha, Burmodilla, Killi Mukku and Gilli Mukku. The fruit size is medium to large, its shape is oblong with necked base and colour is golden yellow. Fruit quality is poor but keeping quality is very good. It is widely used for processing. It is a mid-season variety.
3. **Banganapalli** : It is a commercial variety of Andhra Pradesh and Tamil Nadu. It is also known as Chapta, Safeda, Baneshan and Chapai. Fruit is large in size and obliquely oval in shape. The colour of the fruit is golden yellow. Fruit quality and keeping quality are good. It is a mid season variety and is good for canning. 4. Bombai : It is a commercial variety from Bihar state. It is also known as Malda in West Bengal and Bihar. Fruit size is medium, shape ovate oblique and colour is yellow. Fruit quality and keeping quality are medium. It is an early season variety.
4. **Bombay Green** : It is commonly grown in north India due to its early fruiting quality. It is also called Malda in northern India. Fruit size is medium, shape ovate oblong and fruit colour is spinach green. Fruit quality is good and keeping quality is medium. It is a very early season variety.
5. **Dashehari** : This variety derives its name from the village Dashehari near Lucknow. It is a leading commercial variety of north India and one of the best varieties of our country. The fruit size is small to medium, shape is oblong oblique and fruit colour is yellow. Fruit quality is excellent and keeping quality is good. It is a mid season variety and is mainly used for table purpose.
6. **Fajri** : This variety is commonly grown in the states of Uttar Pradesh, Bihar and West Bengal. Fruit is very large, obliquely oval in shape. Fruit colour is light chrome. Fruit quality and keeping quality are medium. This is a late season variety.
7. **Fernandin** : This is one of the oldest varieties of Bombay. Some people think that this variety originated in Goa. Fruit size is medium to large, fruit shape is oval to obliquely oval and fruit colour is yellow with a blush of red on shoulders. Fruit quality and keeping quality are medium. It is a late season variety mostly used for table purpose.
8. **Himsagar** : This variety is indigenous to Bengal. This is one of the choicest varieties of Bengal and has gained extensive popularity. Fruit is of medium size, ovate to ovate oblique in shape. Fruit colour is yellow. Fruit quality and keeping quality are good. It is an early season variety.
9. **Kesar** : This is a leading variety of Gujarat with a red blush on the shoulders. Fruit size is medium, shape oblong and keeping quality is good. It is an early season variety.

10. **Kishen Bhog** : This variety is indigenous to Murshidabad in West Bengal. Fruit size is medium, fruit shape oval oblique and fruit colour is yellow. Fruit quality and keeping quality are good. It is a mid season variety.
11. **Langra** : This variety is indigenous to Varanasi area of Uttar Pradesh. It is extensively grown in northern India. Fruit is of medium size, ovate shape and lettuce green colour. Fruit quality is good but keeping quality is medium. It is a mid season variety.
12. **Mankurad** : This variety is of commercial importance in Goa and in the neighbouring Ratnagiri district of Maharashtra. The variety develops black spots on the skin in rainy season. Fruit is medium in size, ovate in shape and yellow in colour. Fruit quality is very good but keeping quality is poor. It is a mid season variety.
13. **Mulgoa** : This is a commercial variety of south India. It is quite popular among the lovers of mango owing to high quality of its fruit. Fruit is large in size, roundish oblique in shape and yellow in colour. Fruit quality and keeping quality are good. It is a late season variety.
14. **Neelum** : This is a commercial variety indigenous to Tamil Nadu. It is an ideal variety for transporting to distant places owing to its high keeping quality. Fruit is medium in size, ovate oblique in shape and saffron yellow in colour. Fruit quality is good and keeping quality is very good. It is a late season variety.
15. **Samarbehisht Chausa** : This variety originated as a chance seedling in the orchard of a Talukdar of Sandila district Hardoi, U.P. It is commonly grown in northern part of India due to its characteristic flavour and taste. Fruit is large in size, ovate to oval oblique in shape and light yellow in colour. Fruit quality is good and keeping quality is medium. It is a late season variety.
16. **Suvernarekha** : This is a commercial variety of Visakhapatnam district of Andhra Pradesh. Other synonyms of this variety are Sundari, Lal Sundari and Chinna Suvernarekha. Fruit is medium in size and ovate oblong in shape. Colour of the fruit is light cadmium with a blush of jasper red. Fruit quality is medium and keeping quality is good. It is an early season variety.
17. **Vanraj** : It is a highly prized variety of Vadodra district of Gujarat and fetches good returns. Fruit is medium in size, ovate oblong in shape and colour is deep chrome with a blush of jasper red on the shoulders. Fruit quality and keeping quality are good. It is a mid season variety.
18. **Zardalu** : This variety is indigenous to Murshidabad in West Bengal. It derives its name from Zardalu, a dry fruit popular in North West Frontier Province and Sindh in Pakistan owing to similarity in shape. Fruit size is medium, oblong to obliquely oblong and golden yellow in colour. Fruit quality is very good. Keeping quality is medium. It is a mid season variety.

Grade: Details of grade designation and sizing of mango as per AGMARK standards.

Grade	Grade requirements
Extra class	Mangoes must be of superior quality. They must be characteristic of the variety. They must be free of defects, with the exception of very slight superficial defects, provided these do not affect the general appearances of the produce, the quality, the keeping quality and presentation in the package.
Class I	Mangoes must be of good quality. They must be characteristic of the variety. Mangoes may have following slight defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package. - slight defects in shape; - slight skin defects due to rubbing or sunburn, suberized stains due to resin exudation (elongated trails included) and healed bruises not exceeding 2,3,4,5 sq. cm. for size groups A, B, C, D respectively.

Class II	This grade includes mangoes which do not qualify for inclusion in the higher grades but satisfy the minimum requirements. Mangoes may have following defects, provided they retain their essential characteristics as regards the quality, keeping quality and presentation. - defects in shape, slight skin defects due to rubbing or sunburn, suberized stains due to resin exudation (elongated trails included) and healed bruises not exceeding 4,5,6,7 sq. cm. for size groups A, B, C, D respectively

Disease and Management

(a) Anthracnose: Colletotrichum gloeosporioides

Symptoms

- Produces leaf spots, blossom blight, wither tip, twigs blight and fruit rot.
- Small blister like spots develop on the leaves and twigs. Young leaves wither and dry Tender twigs wither and die back symptom appears.
- Affected branches ultimately dry up. Black spots appear on fruits.
- The fruit pulp becomes hard, crack and decay at ripening. Infected fruits drop

Figure 94. Anthracnose

Management

- Spray P. fluorescens (FP 7) at 3 weeks interval commencing from October at 5g/like on flower branches.
- 5-7 sprays one to be given on flowers and bunches.
- Before storage, treat with hot water, (50-55°C) for 15 minutes or dip in Benomyl solution (500ppm) or Thiobendazole (1000ppm) for 5 minutes

(b) Stem end rot: Diplodia natalensis

Symptoms

- The dark epicarp around the base of the pedicel

- In the initial stage the affected area enlarges to form a circular, black patch
- Under humid atmosphere extends rapidly and turns the whole fruit completely black within two or three days.
- The pulp becomes brown and somewhat softer.
- Dead twigs and bark of the trees, spread by rains

Figure 95 Stem end rot

Management

- Prune and destroy infected twigs and spray Carbendazim or Thiophanate Methyl(0.1%) or
- Chlorathalonil (0.2%) as fortnightly interval during rainy season.

Maturity indices for harvesting:

For long distance markets, fruits should be harvested at early maturity. However, fruits should not be immature.

In order to ascertain appropriate levels of maturity of the fruits, following parameters should be carefully observed to avert spoilage:

i) Fruit should be harvested at light green color stage of mango peel (skin)
ii) Fruit should be harvested with a specific gravity of 1.0 or slightly less. The incidence of spongy tissues increases with an increase in specific gravity.
iii) Total soluble solids (TSS) of mango fruit is recommended to be between 7 to 8%.
iv) Fruit acidity recommended: pH 4.0
v) The fruits of uniform characteristics (as listed above) should be harvested and packed to ensure uniform ripening.
vi) Consignment lot should comprise of fruits harvested at the same period Harvesting should be planned to keep in view the above factors.

Time of Harvesting:

The fruits should be harvested in the morning (before 10 AM) or evening (after 5 PM). Harvesting after 10 AM and before 5 PM should be avoided in order to ensure reduction of field heat in the fruits. Harvesting should be performed 48 hours in advance of shipping.

Method of harvesting:

For harvesting of the fruits, specially designed mango harvesters (stalk clippers) should be used to improve the quality and shelf life of the fruit. For bigger trees the pickers should climb the branches with cotton or fiber bags that they fill and lower to the ground. It is recommended that after harvesting, the fruits should be immediately kept under shade at safe and clean place until it is transported to the packhouse. For ensuring the quality and shelf life of the fruit, it is advisable that fruits be air/potable water cooled under the shade till harvesting is completed. This will minimize the effect of high temperature on the fruit and would decelerate the ripening process.

Figure 96 Mango harvesting with Harvester

Transportation to the pack house:

The fruits should be quickly transported in fully covered vans to pack house. Efforts should be made to pack the fruits in the nearest pack house to minimize the delay and to avoid damage to the fruit during transit.

Figure 97 Mango transportation through pick up van

Post-Harvest Process:

De-sapping: Acidic Fruit sap oozing out from the fruit harvested from stalk end results into severe damage to the skin and leaves the brown / black sap marks effecting the overall look of the fruit. Hence it is advisable to harvest the fruits keeping minimum half inch to one-inch stalk so that fruit sap does not ooze out or desapping process shall be followed immediately after harvesting in the orchard itself to avoid sap damage

(a) De-sapping is a process of removing the sap from mango fruit.

The sap from the fruit is removed by cutting the stalk of the fruits at a length of 5-10 mm from the base of the fruit with the help of a sharp-edged scissor/harvester. At the time of stalk cutting, the fruit should be held upside down so as to avoid the flow of sap on the skin of fruit. It is advisable that whole sap from the fruit should come out during the de-sapping process. However, to reduce the process time, fruits should be placed upside down at least for 45 minutes. This process should be undertaken by only trained/skilled workers of the pack house so that skin of the fruits is not damaged. It would be appropriate if fruits are washed with water by applying a forced jet system of spraying. This will considerably hasten the process of de-sapping and ensure proper coverage of the fruit by the spraying water.

Cleaning and washing of fruit:

(a) After de-sapping, the fruits should be washed carefully for 2-3 minutes to remove any patches of sap.
(b) During washing, fruits should also be cleaned with soft brushings.
(c) The washing is recommended to be done with only fresh potable water of temperature lower than that of the fruit.
(d) Neutral detergents like Teapol, Sandovit or Indtron at 0.1% (1 ml of detergent per litre of water) may be mixed with water to help remove latex (sap).
(e) It is recommended that the Alphonso mango shall be subject to specific gravity test for removal of fruits affected by the internal disorder – spongy tissue disorder.
(f) This may be done by transferring the fruit to a tank containing 2.5% salt solution. The mangoes which sink down are over mature and are likely to be affected by spongy tissue disorder. The mangoes which float in the salt solution are at the right stage of maturity for export.

Figure 98 Washing of Mango to remove foreign material.

Hot-Water Treatment Fruits intended for Exports shall be subjected to Hot water Treatment:

(a) After de-sapping and washing, mango fruits should be passed through hot water treatment tanks fitted with thermostat control sensors to maintain the desired temperature of 52^0C.
(b) The hot water should be treated with disinfectant such as sodium hypochlorite/prochlorazetcat 200 ppm concentration for 3-4 minutes.
(c) After hot water treatment fruits are passed through the drying table to remove the moisture.
(d) The fruits are then cleaned/wiped by a soft muslin cloth/automatic sponge system and transferred to sorting/grading table.

Sorting and Grading:

Over-sized/under-sized /blemished /diseased/damaged fruits shall be removed at sorting table. Though maturity indices are observed at harvesting stage as mentioned above it is advisable to observe the maturity index at this stage as well. Mango falling in uniform criteria shall be graded and packaged accordingly. Mangoes should be handled carefully and placed gently into the packing boxes to avoid bruising/injury. Mangoes shall be graded as per size, weight, shape and color or as per the market requirements.

Figure 99 Manual sorting and grading of Mango

Pre-cooling: Mangoes are intended for export should be pre-cooled to 12-13 Deg C using forced air pre-cooling as soon as possible after harvesting.

Packaging and palletization:

It is advisable that packaging should be carried out on tables instead of floor for maintaining proper hygiene.

Fruits shall be placed into soft, expandable polystyrene, netted sleeves to prevent bruising before placing into the final packaging boxes.

Mango fruits should be packed in single layer within the self-locking fiberboard carton boxes.

The bursting strength requirement of the packages should be more than 260 lb/in2.

The packing material should have waterproof coating to prevent damage to the fruits.

Adequate ventilation (openings) shall be provided in the boxes and such ventilators (openings) in the box shall be covered with an insect proof screen of 30 mesh per liner inch (Mandatory for USA and Japan).

Packing material of only food grade quality shall be used for packing of fruits.

Carton labelling shall be done in accordance with the market requirement.

After packaging, palletization is very essential in case of sea shipments to reduce the fruit damage due to multiple handling. The pallet size should be 1200 x 1000 mm.

The pallets should be secured with horizontal plastic straps and stacking operation should be done carefully.

Stacked packages shall be immediately loaded into the container maintaining a temperature of 120 C with a relative humidity of 90-95% .

Figure 100 Mango Packaging & palletization.

Container loading:

Mangoes shall be shipped to local destination markets within 24 hours of harvesting in covered vehicles at ambient temperature.

In case of Exports Before the fruit should be pre-cooled to 12 C and be transported in reefer containers at 12 Deg C. and at 90-95% RH

In-Transit processes: In case of Exports The temperature during transport should be monitored meticulously. The temperature of 12C shall be maintained throughout the transit period. It would always be advisable if data loggers are placed inside the container to monitor the temperature and RH throughout the transit period.

Storage:

Mangoes ripen within 4 to 6 days, after harvest at the mature green stage.

The ripe fruits have a shelf life of 2 to 4 days.

Storage at 10 to 12o C and 85 to 90 % of relative humidity, will maintain mango in acceptable conditions for up to 4 weeks and fruits will then ripe satisfactorily at higher temperature. These conditions will however depend on the variety, maturity at harvest and tome of harvest.

Figure 101 Mango storage and ripening chamber

14.10 Papaya

The papaya fruit, being a living entity, is subject to continuous change until it completely deteriorates. While some changes are desirable such as ripening (trail figure), many post-harvest changes cannot be prevented, but the rate can be slowed with good post-harvest handling. Good post-harvest management practices can only maintain, not improve, the quality of harvested fruit. The main objective of post-harvest

handling, therefore, is to maintain the quality and safety of fruit between the producer and the consumer

Figure 102 Changes in the papaya as the fruit ripens.

Diseases and Management

(a) Stem rot / Foot rot: Pythium aphanidermatum

Symptoms

- Water-soaked spot in the stem at the ground level which enlarge and griddle the stem.
- The diseased area turns brown or black and rot.
- Terminal leaves turn yellow droop off.
- The entire plant topples over and dies.
- Forward by rain. R. solaniis favoured by dry and hit weather.Common in 2-3 year old trees.

Figure 103 Stem rot

Management

- Seed treatment with Thiram or Captan 4 g/kg or Chlorothalonil.
- Drenching with Copper oxychloride 0.25 % or Bordeaux mixture 1% or Metalaxyl 0.1%

(b) Papaya ring spot: Papaya ring spot virus

Symptoms

- Vein clearing, puckering and chlorophyll leaf tissues lobbing in.
- Margin and distal parts of leaves roll downward and inwards, mosaic mottling, dark green blisters, leaf distortion which result in shoe string system and stunting of plants.
- On fruits circular concentric rings are produced.If affected earlier no fruit formation.
- Vectored by aphids Aphis gossypii, A. craccivora and also spreads to cucurbits not through seeds.

Figure 104 Papaya ring spot

Management

- Raise papaya seedlings under insect-proof conditions.
- Plant disease free seedlings.
- Raise sorghum / maize as barrier crop before planting papaya.
- Rogue out affected plants immediately on noticing symptoms.
- Donot raise cucurbits around the field.

Harvesting

Papaya is one of the most susceptible fruits to skin damage. Papaya farmers can minimize fruit damage by taking protective measures throughout all handling stages: use the harvesting tools properly and avoid dropping the fruits into the boxes and overfilling, latex stains should be avoided, and transport the fruit carefully.

Harvesting maturity

Papayas are ready for harvesting when most of the skin is yellow green, called the “one yellow stripe” If harvested before this stage papayas will fail to ripe completely. For the local market, particularly in the winter months, papaya should be allowed to color well, before picking; in this case the fruits are more susceptible to damage and bruising during handling.

Papayas are preferably harvested during mid-morning to late afternoon to minimise latex stains on the fruit, which are unsightly and detract from consumer appeal. Every effort must be made to avoid harvesting papaya after it rains since the fruit will be more prone to decay.

Harvesting method

Home growers usually twist the fruit to break the stem. In commercial operations it is preferable to use a sharp knife to cut the stem and then trim it to the base of the fruit. Harvesting of high fruits can be done with a harvesting pole with a small hoop and a small mesh bag at the end. Above the hoop is a horizontal blade, which cuts the fruit which will fall into the bag below. Another system consists of a harvesting pole with a cup attached held against the lower end of the fruit and twisting it. In this case the picker will then need to catch the falling fruits. Latex can irritate the skin of the pickers: protection with gloves is advisable.

When trees are within easy reach, papayas are harvested by hand using a clean, sharp knife to detach the papaya from the trunk of the tree. For tall trees, appropriate harvesting tools can be used such as a picking pole with cloth or net attached at the end, to catch the harvested fruit (Photo 8). If the tree is too tall to be reached with a picking pole, a ladder should be used when harvesting the fruit.

Figure 105 Tools used to harvest papaya and plastic crates are suitable field containers

Collecting containers or field containers must be lined with clean paper or papaya leaves to protect the fruit from punctures and cuts caused by the sharp or protruding edges of the container. Note that plastic crates are the most appropriate collecting containers.

Harvested fruit must not be placed on the ground. Harvested papayas should not come in contact with the soil so as to avoid microbial contamination (figure 105).

Field containers and the harvested fruit must be temporarily left under shade to avoid exposure to the sun. Heat build-up during exposure to the sun will result in water loss and may speed up ripening.

Good personal hygiene must be practiced during harvesting and field handling to avoid cross-contamination of the produce.

Fig 106 Newly harvested fruit in plastic crates held in a share area.

Post-harvest handling

Post-harvest operations are those undertaken to prepare the produce to meet the requirements of the target market. These operations can be carried out in the field, at collection centres or in the packinghouse. The packinghouse must provide adequate protection from sun and rain and must be kept clean at all times. Animals should not be allowed into the packing area and all workers should practice good hygiene.

Trimming: Trimming refers to cutting the stem that is left on the fruit (Figure 107). If the papaya is packed with the long stem attached, it may injure the peel of other fruit in the container. Scratching, which may not be seen at the unripe stage, may appear as discolouration on the skin of the ripe fruit.

Figure 107 simple packinghouse for papaya where operations such as trimming, and washing are performed

Cleaning/washing

Infestations by insects such as scale insects and mealy bugs, sooty moulds and even latex stains are sometimes visible on the fruit and reduce consumer appeal.

Washing the fruit in water or in 1 percent alum solution cleans the surface of the fruit and removes any latex adhering to the peel.

Cotton gloves should be used to protect the fruit from cross contamination; they also protect the hands when removing dirt and other foreign matter stuck to the fruit.

The gloves and the water used for washing should be clean. The gloves should be washed after they have been used.

Before packing, the fruit should be air-dried on slatted bamboo trays or in front of blowers.

Consumers are more likely to reject papayas if they show the following defects:

- ► insect damage caused by scale insects, mealy bugs, white flies
- ► pre-harvest damage such as sooty mould and sunburn
- ► damage from harvesting and handling such as latex stains, abrasion, cuts and punctures; and
- ► premature ripening.

Post-harvest diseases

The two most important post-harvest diseases affecting papaya are anthracnose and stem end rot.

Anthracnose infection may occur even before harvest, but symptoms appear as the fruit ripens.

Stem end rot infection becomes visible during the early stage of ripening.

A combination of pre- and post-harvest disease management will ensure adequate control of these diseases.

Post-harvest disease control

Hot water treatment (HWT) is by far the most effective post-harvest treatment against post-harvest diseases. The treatment consists in dipping mature papayas for 5 to 10 minutes in water heated to 49 to 51 °C. At this temperature range, the decay-causing organisms are killed without injuring the fruit.

Procedure for the hot water treatment

• Fill the tank with enough clean water to completely immerse the fruit-filled crate in heated water (about 3/4 of the total depth of the tank).

• Heat the water to 51 °C. The temperature should be checked at different points in the tank.

• Transfer the papayas to be treated into plastic crates. The crate protects the fruit from being injured by the heat because it prevents contact with the hot sides and bottom of the tank. Since, papayas

float in water, place a cover, such as a net on top of the crates.

• Dip the crates in hot water for 10 minutes

- If there is no pump to circulate the water, stir the water occasionally to ensure a uniform temperature in the tank.
- The treatment can be shortened to 5 minutes if the papayas are produced during the dry hot period when conditions are unfavourable to infection in the field.
- Do not allow the temperature to rise above 51 °C or the fruit will scald or be injured.

• Remove the crates containing the papayas from the tank.

- Cool the treated papayas for 10 minutes by immersing them in cool water (hydro-cooling), if the fruit is to be taken to a distant market. If quicker ripening is desired, fast cooling is not necessary.

• Allow the fruit to cool and dry before packing. Faster drying can be achieved by placing the crates in front of blowers

Ripening in Papaya.

Papayas sold as ripe fruit are ripened before they are distributed to the wholesale and retail markets. Ethylene, the hormone responsible for ripening, is produced naturally by Papaya. Traders generally use calcium carbide for rapid ripening which is banned by the Government due to its ill effects. Ideally Papaya shall be ripened in controlled atmosphere ripening chambers maintained at 30-35 Deg C, 90% RH and 300 PPM Ethylene concentration for 24 hours. Post 24 hours ripening is triggered and fruits start generating its own ethylene gas sufficient to their ripening. Generally, it takes 3-4 days for Papayas to ripen.

Storage

Papaya's harvested at the proper harvesting stage (one yellow stripe) will ripen to 60-70% yellow within 4 to 6 days under ambient tropical conditions (25-28oC).

Papaya's harvested at "one strip stage" and stored at low temperature (10 to12o C) will last from 14 to 21 days, if post-harvest disease incidence can be controlled.

Selection/Grading

- Grading and packing should be carried out as soon as possible after harvest.
- Papaya's after separation of broken or heavily diseased ones, are graded according to size and stage of ripeness.

Packaging

- Good bulk packaging is essential to maintain the quality of papayas during transportation and subsequent handling.
- Rigid containers, such as stackable plastic crates, are highly recommended for the bulk packaging

of fresh papayas since they provide adequate protection against compression damage.

- ► Plastic crates are easy to clean they are stackable, reusable and returnable.
- ► Plastic crates are relatively cheaper and packaging cost per KG could be minimum with 5-6 years of usability if maintained carefully.
- ► Depending on the intended market, the papayas may be individually wrapped in a fruit cup made of polystyrene.
- ► The polystyrene cup provides additional protection to the fruit not only during transport but also during retail handling.
- ► Wooden crates are also rigid bulk packaging containers and provide adequate protection during transport.
- ► Papayas are individually wrapped when wooden crates are used for packaging.
- ► It is advisable that Papaya load could not be more than 25 KG in wooden crate otherwise over packed papayas may show compression damage.

Figure 108 Plastic Crates; Papaya's packed in polystyrene fruit cup/retail display; Individual papaya wrapping in a wooden crate.

Semi-rigid containers such as bamboo basket and large plastic bags are not suitable as containers to package and transporting papayas.

Plastic bags use consideration

Hygiene – plastic crates must be thoroughly cleaned with soap or detergent after every use.

Handling – crates must be handled with care during loading, stacking and unloading. They must not be dropped or used as seats when sorting.

Storage – crates must be stored in a clean area that will prevent infestation by insects and rodents.

- Plastic crates must be stored separately from chemicals and from farm machinery to prevent contamination.
- Crates should not be left exposed to the external environment since they will quickly wear out.

Crates used to transport produce must not be used as storage containers for chemicals (fertilizers and pesticides).

Transport

Papayas generally moves through three major steps:

- From the field to the collection centre
- From the collection centre to the wholesale market
- From the wholesale market to the retail market

Good transport practice is critical to maintaining quality during transportation:

- Bulk packaging containing the papayas must be handled gently and must not be dropped or thrown down.
- Containers at the bottom of the stack must not be used as steps when stacking to a greater height. This is particularly important when semi-rigid containers, such as cartons, are used.
- There is far less risk of damage when stackable plastic crates are used as packaging and transport containers.
- The transport vehicle must be clean to ensure the safety of the produce. Safety can be compromised by:
    - decaying remains of produce from the previous shipment.
    - insects and rodents nesting in the vehicles.
    - use of the vehicle to store farm implements.

- Four-wheeled hand trolleys can be used to minimise delays and to facilitate the transfer of packaged produce from one part of the market to another

Wholesale and Retail Handling

The following basic rules should be applied:

- Containers containing Papaya's must be unloaded with care from the transport vehicle under cover or in the shade to minimise mechanical damage.
- Papayas must be re-sorted using a sorting table; culls must be disposed of properly.
- Papayas must be re-graded according to size, appearance and stage of ripeness, depending on the requirements of the target market.
- When papayas cannot be sold in one day, unsold papayas must be kept in properly ventilated storage.
- Papayas must be displayed in a polystyrene fruit cup to minimise damage when handled by consumers.

Figure 109 Papaya in retail market

14.11 Pineapple

Harvesting maturity:

It is difficult to tell when pineapples are ready to be harvested. Some people judge ripeness and quality by snapping a finger against the side of the fruit. A good, ripe fruit has a dull, solid sound. Immaturity and poor quality are indicated by a hollow thud. However, harvesting should be started when the base of the fruit has changed from green to yellow or light brown. An acceptable quality may also develop before color changes may occur. Often pickers select fruits by size.

(a) Heart rot: Phytophthora parasitica

Symptoms

- The disease causes complete rotting of the central portion of the stem.
- The top leaves turn brown and basal portion of leaves shows sign of rotting with foul odour.

Figure 110 Heart rot

Management

- Affected plantations should be sprayed with Fosetyl AL 0.1%.
- Good soil drainage and use of healthy planting material at helps in minimizing the spread of the disease.

(b) Leaf and Fruit rot: Cyratostomella paradoxa

Symptoms

- Base or butt rot of planting material occurs when they are not dried and packed with little aeration.
- Fungus also destroys older plants by entering through wounds caused in the collar region while weeding or other operations.
- In severe conditions the entire plant may turn dark and rot within two or three days.

Figure 111 Leaf and Fruit rot

Management

The disease can be controlled by dipping planting materials in 0.3% Dithane Z-78 or by spraying on leaves.

Copper fungicide should not be used in pineapple as they cause leaf scorching.

The diseased plants must be destroyed and suckers for propagation should never be collected from the infested area.

Harvesting method and handling:

Fruits are harvested manually by cutting the stalk using a sharp knife or twisting the fruits from the stalk. The harvested fruits are put inside gunny bags, bamboo or other kind of baskets or field crates and sent to the collecting point for grading. Grading and packing can also be done in the field itself. Fruits, after separation of broken and heavily diseased or defective ones, are graded according to size and stage of ripeness and packed in single layer cardboard boxes, on their side.

Figure 113: Pineapple stored in plastic crate and corrugated box.

Storage.

The fruits should be stored, depending from the variety, at 7 to 13o C (45 to 55 o F), 85-95% Relative Humidity for up to 24 weeks. However, it is advisable to store pineapples for no more than 4-6 weeks, because the fruit is chilling injury sensitive, like most of the tropical fruits.

14.12 Pomegranate

Pomegranate (Punica granatum L.) is an important fruit crop grown in India. Major pomegranate producing states are Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Madhya Pradesh, Tamil Nadu Rajasthan. Maharashtra leads 78 percent of India's total area and 84 percent of its total production.

At Orchard

Dry and semi-arid weather with cold winter and high dry summer is best suited to the production of high-quality Pomegranate, the optimum temperature for fruit development is 35 -38 ° C.

It can be grown under different soil types, from low-fertile to high-fertile soil. However, in deep loamy, it gives an excellent yield. It can tolerate salinity and alkalinity in the soil to a certain extent. Soil having a pH range between 6.5 – 7.5 is ideal for Pomegranate farming.

Pomegranate plants can be commercially propagated through hardwood cutting, air layering, and tissue culture.

Main Commercial Pomegranate Varieties grown in India are Bhagwa, Mridula, Ganesh. Jyothi, Jalore Seedless, Kandhari, Phule Arakta, Phule Bhagwa Super and Bhagwa Sindoor. Bhagwa is the most cultivated variety due to its high demand for domestic and export purposes.

The ideal planting distance followed by farmers is 10 to 12 ft (3 to 3.6 m) between plants and 13-15 ft (3.9 to 4.5 m) between rows.

The optimum time for pomegranate planting is in the rainy season (July-August) when sufficient soil moisture is available for plants' optimum growth.

Fertilizer Management: Though pomegranate can be grown even in the less fertile soil. Still, the recommended dose of chemical fertilizers should be incorporated in the pit for better production and quality of fruits. The dose of manures and fertilizers varies according to types of soil fertility, genotypes, region to region.

For Ambe Bahar fertilizers should be given in December, and for Mrig Bahar fruits, fertilizers should be given during May

Training and pruning is a promising technique to control vegetative growth and maintain the shape and size of trees to enable proper light penetration in the centre of the tree, ease in cultural operations, spraying, and fruit harvesting.

There are two methods of training system followed in pomegranate.

1) Single Stemmed Method –In this method, only one main shoot is kept by removing other shoots of the Pomegranate plant.

2) Multi-Stemmed Method – In this method, the Pomegranate plant bush shape is maintained by keeping 3-4 shoots at the base. This method is very popular and commercially adopted by Pomegranate farmers because, even after a shoot borer, one shoot may provide yield instead of the complete loss.

Disease and Management:

(a) Cercospora fruit Spot: Cercospora sp.

Symptom:

- The affected fruits showed small irregular black spots, which later on coalesce, into big spots.

Figure 114 Cercospora fruit Spot

Management:

- The diseased fruits should be collected and destroyed. Two to three spray at 15 days interval with Mancozeb 0.25%.

(b) Fruit Rot (Aspergillus foetidus):

- The symptoms are in the form of round black spots on the fruit and petiole. The disease starts from calyx end and gradually the entire fruit shows black spots. The fruit further rots emitting a foul odour.

Figure 115 Fruit Rot

Management

- The disease can be controlled by spraying of Bavistin (0.5%), Dithane M-45 (0.25%) or Dithane Z-78 (0.25%) at an interval of 10-15 days from the onset of flowering.

Harvesting: Pomegranate harvesting is started after 150 to 180 days from flowering to fruit maturity. But it depends on genotype, climatic condition, and growing region.

Pomegranate is a non-climacteric fruit and maturation virtually stops as soon as it is harvested. hence should be harvested at the optimum maturity stage because early harvesting results in the dull, immature, and improper ripening of fruits. In contrast, late harvesting leads to more prone to the attack of disorders. However, that should be harvested after at proper ripening stage.

There are several harvest signs used to assess the maturity and harvesting of pomegranate fruits. Dark rose pink colour should develop on the surface and dark pink aril mostly preferred by the consumers.

The calyx at the bottom of Pomegranate fruits gets turn inward side is also a maturity index. Aril should be turned in deep red or pink. Fruits of pomegranate should not be over-ripened.

Fruits should be harvested with secateurs or clippers' help because manual twisting may cause damaged fruits in clusters.

Postharvest Handling: After harvesting, fruits should be sorted out to remove diseased and cracked fruits, after sorting, fruits should be washed with sodium hypochlorite solution at the rate of 100 ppm in water. This treatment will be helpful to reduce microbial contamination and to maintain a longer shelf-life.

Pre-Cooling: Fruits should be pre-cooled before storage to remove vital heat and field heat of produce which results in shelf-life enhancement of fruits. For pomegranate fruits, the forced air-cooling system is used for pre-cooling. Hence it should be maintained around 5ºC with 90% relative humidity.

Grading of Fruits: Pomegranate fruits are graded based on their size and weight; however, grading standards vary from country to country. However, grade specifications as per National Horticulture Board for the export purpose are as follows.

Grade	Fruit weight
Supersize	750 gm
King size	500-700 gm
Queen size	400-500 gm
Prince size	300-400 gm

Packing for wholesale: Pomegranate fruits are packed in wooden boxes, plastic crates and corrugated fibreboard boxes. The capacity of the box should be 4 kg or 5 kg. According to AGMARK specifications dimension of the 4 kg capacity box is 375×275×100 mm3 and for the 5 kg box is 480×300×100 mm3

Figure 116 Pomegranate wholesale packing.

Packing for Retail: 6 -12 Pomegranates may be shrink packed in fibre or plastic trays or cardboard boxes, further packed in to corrugated cartons or plastic Crates for safe transportation to Retail outlets

Storage: The very low temperature may induce chilling injury in fruits, ideal temperature for the storage of fresh pomegranates is 6° to 7°C and 90 to 95% Relative Humidity. At this temperature, Pomegranate fruits can store up to 3 months.

Transport: Use covered tight-packed transport. For distant destination markets and export Pomegranates should be pre-cooled to 7 deg, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 7 deg C.

14.13 Tamarind

Green Tamarind

Dry Tamarind

Harvest operations

Pod yield stabilizes at about 15 years and continues for up to 50 or 60 years. Tamarind fruits are mature and ready for harvesting when a hollow and loose sound is produced by finger pressing, as the pulp shrinks with maturity and the shell becomes brittle. Also, the change in testa color might indicate the maturity of the fruit. However, it is not always easy to determine whether the fruits are ready for harvesting, as the testa color only changes slowly as the pods mature. Individual fruits on the tamarind

tree also mature at different times, making selective harvesting necessary. Pods are harvested at different stages of ripeness, according to how they are going to be used. Immature green fruits are usually harvested earlier for flavoring.

In most countries, the sour tamarind ripe fruits are usually gathered by shaking the branches and collecting the fruits that have fallen; the remainder of the fruit is left to fall naturally when ripe. Sweet tamarind fruits tend to gain higher market prices, and therefore are carefully picked by hand. To avoid damaging the pods and to increase the marketability of both sweet and sour types, harvesting by clipping should be practiced. Pickers should not knock the fruits off the tree with poles, as this will damage developing flowers and leaves.

Generally, the fruits are left to ripen on the tree before harvesting, so that the moisture content is reduced to about 20%. If not harvested, the pods may remain hanging on the tree for almost one year after flowering and sometimes until the next flowering period, and eventually will fall naturally. Fruits for immediate processing are often harvested by pulling the pod away from the stalk, which is left with the long, longitudinal fibers attached.

Beetles and fungi readily attack ripe fruit in humid climates, and therefore they should be harvested before they are fully ripe.

Sorting & Grading

One of the most important operations in a packing line is sorting for maturity, color, shape, size, and defects. The efficiency and effectiveness of sorting govern the quality standard of the packing lines and product, which in turn determines the market ability of the product. Manual sorting continues to be the most prevalent method used, although it is costly in terms of labor and time. Also, the lack of trained labor is one of the reasons that manual sorting may become inefficient and cause damage. One of the most practical and successful techniques for nondestructive quality evaluation and sorting of agricultural products is by judges the optical properties of the product. Electro-optical technique, which can be used to detect color uniformity, shape, size, external defects, for materials, and disease, has been used for postharvest grading for a wide variety of agricultural products including tamarind.

Figure 117 Harvesting and manual sorting & grading of tamarind.

Control of ripening and senescence

Tamarind fruit, as a non-climacteric, will not ripen any further after harvest.

The flavor, juice, sugars and some other contents remain unchanged.

No information is readily available on techniques for controlling tamarind ripening.

Storage and shipping

The high soluble solids content to titratable acidity and the low water content of tamarind fruit contributes to its long storage-life.

Tamarind can be stored with the shell, or as a separated dry pulp, and tightly packaged pods can be stored at 20°C for several weeks.

Figure 118 Tamarind in a degradable plastic bag used for retailing.

14.14 Watermelon

Harvesting:

Harvesting maturity.

Ripeness in watermelons is difficult to determine because the fruit remain attached to the wine, rather than ‘slipping off”.

Harvesting generally begins about 30 days after full bloom and continues with periodical cuts at 3 to 5 days intervals.

The most recommended method for timing the harvest of watermelons is to cut a few representative fruits in the field. However, also the following indicators of ripeness will help:

- The tendrils of the leaf closest to the fruit attachment become dry.
- Change in ground spot color from greenish white to pale yellow.
- The rind becomes hard to pierce with the fingernails.
- Blossom end" fill out'; and
- The sound of a fruit, when thumped with a finger, is a muffed, dull tone if it is ripe.

Disease and Management

(a) Gummy stem blight Didymella bryoniae

Symptoms:

- Round or irregular brown lesions with faint concentric rings on cotyledons; brown or white lesions on crown and stems; soft, circular brown lesions on fruit; lesions on stems and fruit may be oozing an amber colored sticky substance.

Figure 119 Gummy stem blight

Management:

- Use disease free seed; treat seeds prior to planting; rotate crops every 2-3 years to a non-cucurbit to reduce disease build up in soil; reduce crop residue in soil by plowing plant debris into soil after harvest; application of preventative fungicides is usually required to control the disease successfully.

(b) Angular leaf spot Pseudomonas syringae

Symptoms:

- Small water-soaked lesions on top or sides of fruit which enlarge over surface; lesions on fruit may turn reddish or brown and crack

Figure 120 Angular leaf spot

Management:

- Use pathogen-free seed and transplants; rotate crops; avoid the use of overhead irrigation

Harvesting method:

Watermelons are harvested in the afternoon by cutting the stem with a sharp knife rather than pulling the fruit out. Afternoon harvest may reduce the risk of cracking if the field has received abundant water during the previous night. If plants are not too turgid field heat can be minimized by harvesting in the morning. Watermelons do not ripen off the vine. However, holding them for 7 days and over at room temperature will improve flavor and color in seeded varieties.

Take care of the wet and dirty soil, if watermelons get dirty clean them with a wet and clean cloth.

Field assembly and packaging.

After harvesting, watermelons are stacked in the field itself, on the side rather than on end to reduce the risk of cracking. Placing them in a shaded area will allow to minimize the buildup of heat and avoid quality reductions. Packaging in fiberboard boxes or bulk loaded in bins in the field itself taking care to load only dried rather than dew-covered fruits.

Figure 121 Watermelon stored in fiberboard box

Post-harvest

Cleaning and packing are done in the field itself, when the field is easily accessible.

Storage

At 10 to 15o C and 90% relative humidity the fruits can be kept for 2 to 3 weeks after harvest.

Prolonged storage will be responsible for reduction in crispness and color.

Transport: Use tightly packed transport to avoid vibratory and pressure damage to the fruits. Watermelons are generally transported loose in the trucks with cushioning material on the bottom and sides of the vehicle. For best results transportation is recommended in corrugated carton to avoid the pressure damage to the bottom layer

Post-harvest losses

Chilling injuries (the pit in the ring will be invaded by microorganisms) will take place after storage below 5^0 C.

15.0 Produce / item wise protocol for selected vegetables

15.1 Baby corn

AT FARM

A wide variety of soils is suitable. It is important that the soil be well drained and well supplied with organic matter and has high moisture retaining capacity. The optimum pH range is 5.8 to 7.0.

- Common smut caused by a fungus (Ears, tassels, leaves have gray gnarled growths (galls) that become powdery can be controlled by removing and destroying galls as soon as noticed.

- Prevent black powder in galls from getting into soil.
- Use resistant varieties.
- Plant early in the sowing period as late sowing results in higher frequency of problems
- Use Mosaic virus resistant varieties, there is no control available for mosaic virus.
- Stalk and ear rot caused by several fungi (Brown lesions on stalks near joints stalks rotted inside. Kernels pink or moldy) can be controlled by removing old plant debris and maintaining uniform soil moisture.
- Maize dwarf mosaic virus (Stunted plants with yellow and green stripe or mosaic pattern; older leaves pale yellow) can be controlled by controlling weeds and aphids, destroying affected plants and use of resistant varieties.

Good management practices are essential if optimum yields are to be realized. These practices include use of recommended varieties, selection of adapted soils, weed control, disease and insect control, good seed bed preparation, proper seeding.

Timeliness is the most important consideration in harvesting. Ideally, Baby corn has to be handpicked at or within, one to two days after silks emerge from the ear tip. Sort and grade immediately after harvesting in shade. Do not tip from harvesting containers. Do not heap on ground. Keep covered with wet jute sacks or sheet. Handle gently while peeling to ensure that ears do not break during de-husking. Keep peeled baby corn in shade covered with wet sacks.

AT COLLECTION CENTER

Fresh unpeeled Baby corn is moderately perishable, within a few days at ambient temperatures, husks dry out very quickly, silks dry and darken, and cobs ‘sweat’ and caramelize, resulting in significant quality deterioration.

Fresh peeled Baby corn is highly perishable in hot weather. For every 5°C increase in pulp temperature, sugar breakdown to starch doubles, meaning that sweet corn can completely loses flavor in a short period of time.

Peeled Baby corn of excellent quality is straight, has uniform ovary alignment, is 2.5 to 4 inches Long, 0.25 to 1 inch in diameter, slightly yellow to cream color, sweet and not fibrous. Cobs must be free from bites of corn borer, must be clean and not broken.

Check for sorting grading. Handle gently at all times, do not jumble pack, arrange properly in recommended pack. Keep in cool place, do not keep in sun.

PACKING FOR WHOLESALE

Unpeeled baby corn should be packed in 5 kg branded corrugated trays or crates. Peeled baby corn should be packed in perforated poly pouches. Weight per pack may be 500 gm to 1 kg as may be required by various wholesalers further packed in 5 kg branded corrugated trays / cartons.

Figure 122 Baby corn in plastic crates

PACKING FOR RETAIL

250 gm peeled and unpeeled baby corn should be packed in perforated poly pouches or shrink packed in plastic trays further 5 kg packed in branded corrugated trays / cartons.

Pre-cooling to 2 deg C is highly recommended for peeled baby corns as early as possible after de-husking even if it is to be transported and sold in ambient conditions.

Figure 123 Baby corn in plastic pellets

TRANSPORT

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export fresh peeled as well as unpeeled baby corn should be pre-cooled to 2^0 C, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 2^0 C. Use temperature data logger in reefer truck to monitor en-route temperature.

STORAGE

If not for immediate dispatch / distribution store at 2^0 C and 90-95% RH.

15.2 Bitter Gourd (Kerala)

AT FARM

To minimize variable fruit size, follow fertilizer and irrigation recommendations. Pick at 2 days intervals to required size. Improve pollination by using bees

To combat diseases, make high (25 CM) beds in the field and follow recommended spraying and drainage procedures, etc. Disease incidences will be less if bitter gourd is grown on trellis because of better ventilation and greater accessibility for spraying.

Harvest at proper maturity when the fruits are tender and have not developed the hard seeds. Does not delay to try and gain weight, as this will lead to oversized, mature bitter gourd with hard seeds inside.

Harvesting is recommended in the morning and evening hours only. Use smooth surfaced harvesting containers; do not tip from harvest containers. Do not make heap on ground. Sort and grade immediately after harvest to remove defective fruits as per laid down quality standards.

AT COLLECTION CENTER

Check for sorting grading, handle gently at all times as the ridges are very delicate and should not breakaway during handling and packing. Do not jumble pack in the recommended pack. But arrange properly in the pack. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible.

PACKING FOR WHOLESALE

40 kg in wet loosely woven Hessian bags or 35-40 kg tied in wet jute sheets.

10 kg in crates or branded corrugated trays /cartons

PACKING FOR RETAIL

For retail supplies packing 10 kg bitter gourds in plastic crates or branded corrugated trays can be considered. Ready to retail packing of 1 kg bitter gourd in perforated polythene pouches can also be considered further packed in crates or branded corrugated trays.

Figure 124: Bitter Gourd in plastic crates

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Bitter gourd should be pre-cooled to 10 Deg C and be transported in reefer vehicles with thermostat set at 10 deg C. Temperature data logger shall be used to monitor the temperature e-route

STORAGE

If not for immediate dispatch / distribution store at 2-3 deg C and 90-95% RH.

15.3 Bottle Gourd (LAUKI)


AT FARM

To minimize variable fruit size, follow fertilizer and irrigation recommendations. Pick at 2 days intervals to required size average 500 gm.

Mis-shaped fruits will be reduced by growing on trellis, by improving pollination using bees and maintaining humidity and by pruning out mis-shaped fruits at early stage. Growing on trellis will also reduce incidences of chilling injury during winters.

Insect infestation will be controlled by following spray recommendations and pruning the infested fruits at early stage and discard any that comes to maturity.

To combat black tip and anthracnose spotting make high (25 CM) beds in the field and follow recommended spraying and drainage procedures, etc. Disease incidences will be less if Bottle gourd is grown on trellis because of better ventilation and greater accessibility for spraying.

Harvest at proper maturity when the fruits are tender. Does not delay to try and gain weight, as this will lead to oversized, mature fruits with large and harder seeds.

Harvesting is recommended in the morning and evening hours only. Use smooth surfaced harvesting containers; do not tip from harvest containers. Do not make heap on ground. Sort and grade immediately after harvest to remove defective fruits as per laid down quality standards. Keep in shade.

AT COLLECTION CENTER

Check for sorting grading and tenderness. Handle gently at all times as the skin of tender Bottle gourd is very sensitive to bruises and any bruising will not show up immediately but will appear as brown / black patches after 3-4 hours of injury. Do not jumble pack in the recommended pack. But arrange properly in the pack and interlayer with newspaper. It is better if each fruit is wrapped in newspaper. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible.

PACKING FOR WHOLESALE

20-25 kg tied in smooth cotton sheet or jute SHEET lined with perforated poly liner or 10-12 kg in crates or corrugated trays / cartons interlayer with newspaper.

PACKING FOR RETAIL

For retail supplies packing 10 kg Bottle gourds in plastic crates or branded corrugated trays can be considered.

Figure 125: Bottle gourd in plastic crates.

Fig 126: Bottle gourd wrapped in plastic for retail sell.

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or pallies to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Bottle gourd should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate dispatch / distribution store at 10 deg C and 90-95% RH.

15.4 Brinjals (Egg Plant)

Brinjal Round

Brinjal Long

Brinjal Long Green

At Farm

Brinjals grows very well on a wide range of soils, but it grows well on deep, fertile and well-drained soils having pH in the range of 5.5-6.

It requires along warm season, before fruit maturity. Optimum temperature is 22 to 33 Deg C. It is susceptible to severe frost

Summer and Rabi crops are sown in February-March and October to November respectively. sowing in hilly areas takes place in April and May

To produce high quality Brinjals good healthy, disease free seed lings having 8 to 10 cm height and two to three true leaves grown in a protected nursery shall be planted on raised ridges at uniform plant to plant distance of 75x75 cm for round varieties and 60x60 cm for long varieties

25-30 MT of well decomposed FYM should be mixed in soil before transplanting, NPK @ 50, 80 and 60 kg/ha should be applied before transplantation further 25 kg of nitrogen should be applied each at 30 and 45 days

Generally manual weeding is done, Herbicides like fluchloralin may be applied @ 1.5 kg / ha to control weeds.

Fruits should be harvested when they attain good size and surface is bright with glossy appearance. Harvesting should be done once or twice per week, depending on the variety. Secateurs are needed for hand-harvesting, taking care to handle nicely the fruits and leaving 2 to 4 cm long stem above the calyx. The harvesting of wet fruits should be avoided.

Ventilated field crates should be placed when full, in a shaded place to avoid over-heating. Sacks and bags should be avoided to reduce development of mechanical damage and heat build-up.

Clean with a soft cloth to remove soil and residues from the fruits. Fruits showing yellowing of the skin are over-mature and should be separated, along with fruits presenting signs of decay, insect damage, cracks, sunscald and other mechanical damages.

After size grading, the fruits of the same size should be loose packed in cardboard boxes or plastic crates lined with polythene liner to arrest water loss. Packing in gunny or Hessian bags should be avoided as skin of the Brinjals is very delicate and prone to bruising.

Disease and Management:

(a) Bacterial Wilt: Pseudomonas solanacearum

Symptoms

- Bacterial wilt symptoms on leaf surface Wilting, stunting, yellowing of the foliage and finally collapse of the entire plant are the characteristic symptoms of the disease. Lower leaves may droop first before wilting occurs. The vascular system becomes brown. Bacterial ooze comes out from the affected parts. Plant show wilting symptoms at noontime will recover at nights, but die soon.

Figure 127: Bacterial wilt symptoms on leaf surface

Management

- Use resistant variety. Crop rotation with cruciferous vegetables such as cauliflower help in reducing the disease incidence. Fields should be kept clean and effected parts are to be collected and burnt. Spray Copper fungicides to control the disease (2% Bordeaux mixture.). The disease is more prevalent in the presence of root knot Nematodes, so control of these nematodes will suppress the disease spread.

(b) Cercospora Leaf Spot

Symptoms:

- The leaf spots are characterized by chlorotic lesions, angular to irregular in shape, later turn grayish brown with profuse sporulation at the centre of the spot. Severely infected leaves drop off prematurely, resulting in reduced fruit yield.

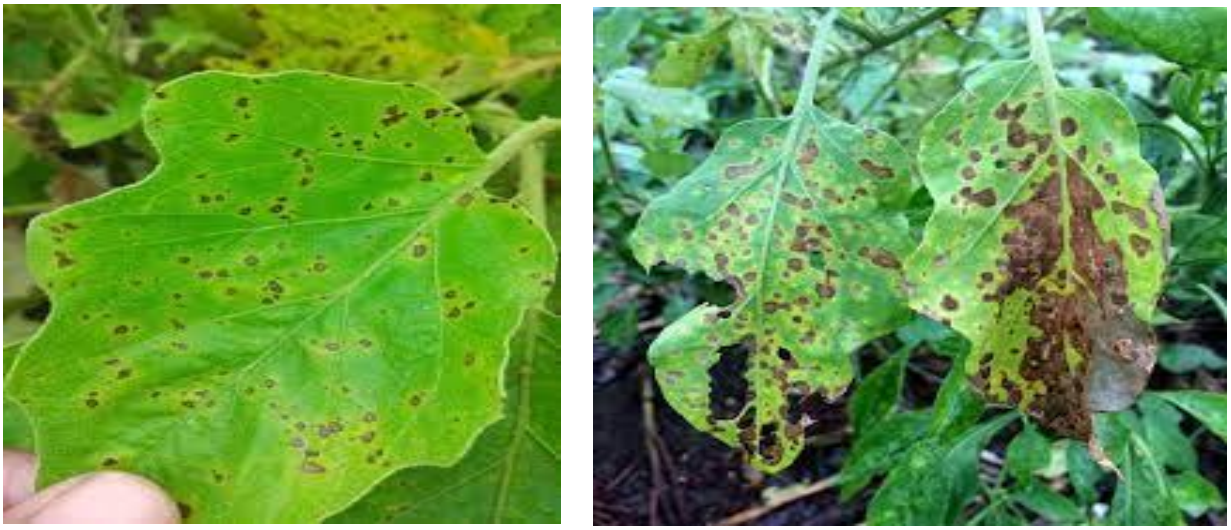


Figure 128: Cercospora Leaf Spot

Management:

Pant Samrat variety is resistant to both the leaf spots. Diseases can be managed by growing resistant varieties. Spraying 1 per cent Bordeaux mixture or 2 g Copper oxychloride or 2.5 g Zineb per litre of water effectively controls leaf spots.

AT COLLECTION CENTER

Check for quality and size grading, keep in cool place, avoid pre-cooling and reefer transport at temperatures below 10 Deg C as Brinjals are prone to chilling injury if temperature goes below 10 Deg C. If brought unsorted by the members, fruits should be sorted graded and packed in corrugated trays or plastic crates with perforated polythene liners.

PACKING FOR WHOLESALE

10 Kg in Corrugated trays / cartons or plastic crates with perforated polythene liner.

Figure129: Wholesale packs of Brinjals Plastic crates with polythene liner

PACKING FOR RETAIL

Brinjals can be packed in perforated polythene pouches or shrink wrapped in fiber trays in sizes of 500 gm to 1 kg. Such ready to sell retail packs may further be packed in corrugated cartons or plastic crates for transport

Figure 130: Retails packs of Brinjals

IN TRANSPORT

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Brinjals should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons or crates with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

Brinjals are stored at 10°C to 12°C with 90% to 95% RH. Storage of eggplant is generally less than 14 days.

Brinjals are temperature sensitive and prone to chilling injury particularly when temps dip below 10 Deg C, including pitting, surface bronzing, and browning of seeds and pulp tissue.

Brinjals are also highly sensitive to ethylene, a natural gas that causes certain foods to ripen (and eventually spoil) very quickly. So Brinjals should be kept away from bananas, tomatoes, and melons, which are all high ethylene producers.

15.5 Capsicum (BELL PEPPER)

AT FARM

There are many varieties with different shapes, colors and flavors. Some of the typically grown varieties in our country are California wonder, Arka Gaurav, Arka Basant, Early Glant, Chinese Glant, World Beater, Yolo Wonder Bharat, Arka Mohini, King of North and Ruby King

To produce high quality capsicum selection of the variety suitable to the climate and soil conditions of growing area, plantation of good healthy, disease free seed lings grown in a protected nursery are of utmost importance.

Capsicum grows very well on most of soils types, however well drained clay loam soil rich in organic matter is best for its growth and yield. The most suitable pH range of soil for capsicum cultivation is 6 to 7.0.5-6. The capsicum crop is very sensitive to frost conditions. The best temperature for capsicum cultivation is 22 to 25 Deg C.

Usually Capsicums are propagated through seeds. Capsicum Seed should be treated with Thiram or Captan @ 2 gms / kg of seed before sowing to prevent any seed borne disease

Capsicum can be grown throughout the year with abundant water facility or in controlled environment like green house, poly house or shade net. Generally, capsicum crop is sown in August for the Autumn winter crop and in November for the spring-summer crop

Capsicum seedlings should be first raised in the nursery beds and then transplanted in the main field. Generally, 45 to 50 days old seedlings of capsicum with 4 to 5 leaves should be transplanted in fields. Seedlings should be transplanted in rows at a distance of 30 to 45 cm. Capsicum crop should be irrigated at an interval of 7-10 days.

Well decomposed FYM of 20 to 25 tons should be added as part of land preparation Inorganic fertilizers of NPK should be applied in the ration of 40:60:30 Kg per ha as basal application. Potassium and phosphate fertilizers should be mixed in the plant rows just before transplanting and 40 kg of Nitrogen shall be applied on 30th, 60th and 90th day of transplanting.

Weed control is a part of intercultural operation and should be practiced for quality produce and crop yield.

Sweet pepper fruits are usually picked when they have stopped increasing in size, are firm to the touch and in the green turning yellow/red stage. Hot varieties are harvested either immature (green) or mature (yellow/red) stage for fresh use or processing.

All peppers are harvested by hand, with approximately 1 to 2 cm of stem attached, and introduced into baskets that are then emptied into field boxes for delivery to the pack-house or in single layer cardboard boxes for the market. Harvested capsicum should be placed in the shade immediately after harvest.

AT COLLECTION CENTER

Check for quality and size grading, keep in cool place, Small lots brought unsorted by the members, should be sorted graded and packed in corrugated trays or plastic crates with perforated polythene liners and transported to local market in normal trucks at ambient temperature.

If pre-cooling facility is available pre-cool to 10 Deg C and reefer transport at thermostat set at 10 Deg. Capsicums are prone to chilling injury if temperature goes below 4 Deg C.

PACKING FOR WHOLESALE

5-10 Kg in Corrugated trays / cartons or plastic crates with perforated polythene liner.

Figure 131: Wholesale packs of Capsicum Plastic crates / Corrugated Trays

PACKING FOR RETAIL

500 gm to 1 kg in perforated polythene pouches or net bags may be considered for ready to sell retail packs, these packs may further be packed in crates or cartons for transport purpose.

Figure 132: Retail packs of Capsicums in perforated Polythene Pouches and net bags

IN TRANSPORT

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Capsicums should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons or crates with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate sale / distribution may be stored at 7-10 Deg C and 90-95 % RH. Care shall be taken as Capsicums are prone to chilling injury below 4 Deg C

15.6 Carrots (RED AND EUROPEAN)

AT FARM

Size uniformity can only be achieved through sowing improved varieties, and by row cultivation combined with equal inter-plant spacing, thinning, and recommended fertilizer, irrigation and drainage practices. This will also reduce mis-shaped and forked roots, thick core and natural growth cracks, bacterial blight, root scab and pale color. Size grades and defects should be separated at farm.

Problem of Green top will be reduced by sowing at correct depth and by following recommended irrigation and drainage methods.

Rough, coarse roots can be reduced by better soil selection.

Root nodes and secondary roots can be controlled by selecting soils free from nematodes and using Furadan or phorate. Spray against leaf hoppers to control aster yellow virus.

Harvest at full maturity but does not delay to try and gain weight, as this will lead to oversized and hard tasteless roots.

Cut leaves close to the root, wash roots properly and allow them to dry before packing in jute sacs or tying in pallies. Free moisture on surface may result into sliminess.

AT COLLECTION CENTER

Check for sorting grading, pack in crates, corrugated trays or 20/40 kg loosely woven wet Hassian bags. Early European carrots can also be sent for sale with leaves in bunches of 1 kg further packed in plastic crates or corrugated cartons.

Figure 133: Grading of carrots

In case of stored carrots proper sorting should be ensured to remove the carrots, which have developed visible defects like rotten spots on surface.

PACKING FOR WHOLESALE

Traditionally Red Carrots are being packed in used jute bags in 70-75 kg. Keeping in view the ease of handling packing in 40 kg in loosely woven wet Hessian bags is recommended for wholesale.

PACKING FOR RETAIL

15 kg in plastic crates or branded corrugated cartons with perforations for air circulation. European carrots can also be shrink wrapped in half kg and one kg packs further packed in corrugated cartons of 10 kg.

Figure 134 Carrots in Plastic crates.

IN TRANSPORT:

Use covered tight-packed transport. Cover crates with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings. In case of cartons sufficient air circulation to be ensured. Material should be dispatched as soon as possible. Ideally for wholesale Carrots should be harvested in the morning, washed, dried throughout the day and should be dispatched after sunset so as to reach mandi after midnight.

Figure 135: Carrot transportation by pick up van.

For distant destination markets and export Carrots should be pre-cooled to 10 Deg C and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate dispatch / distribution store at 2-3 deg C and 90-95% RH.

15.7 Cauliflower

AT FARM

Size uniformity can only be achieved through sowing improved varieties, uniform transplants and by uniform row cultivation combined with equal inter-plant spacing. Size grades should be separated at farm.

Problem of yellowing of curds can best be controlled by bending or tying leaves over curds as they start to develop.

Insect infestation should be controlled by constant crop monitoring and following the proper spraying recommendations given by the plant pathologist and planting a trap crop of 2 rows of mustard after every 24 rows of Cauliflower.

Rotting is controlled by following seed pre-treatment, seedling sanitation and recommended spray program. Gentle handling at harvest and retention of 3-4 wrapper leaves will eliminate external mechanical damage and subsequent rotting of curds.

Pink and purple curds can be reduced by bending or tying leaves over the curds in hot or cold weather, and by including a micronutrient spray with zinc and boron in spray program, which will also reduce hollow stem.

Yellow and loose curds can best be avoided by planting summer and monsoon crop at higher altitudes, some improvement may be possible by bending or tying leaves over curds

Harvest at full maturity but does not delay to try and gain weight, as this will lead to a looser head, cover with wet jute sacs or jute sheet after picking.

Harvesting should be done in cool hours i.e. in morning and evening only. Harvesting immediately after rains should be avoided. Also harvest in the early morning when field is full of dew moisture should be avoided.

AT COLLECTION CENTER

Ensure proper trimming of stem and stalks. Leave two-three inner leaves covering the curd while trimming stalks. Handle the curds gently during trimming to avoid bruising and mechanical damage to the curds. Any injury will not show off immediately but will develop into a brown patch after 3-4 hours. Sort out defective curds. Pack in single layer in crates or corrugated carton trays which are open from top (at least 2-inch gap between the long flaps. Do not pack in sacs or sheets. Weigh each carton / crate to make standard weight and insert farmer ID. Either provide weight margin for wrapper leaves or pay proportionately lower price. This will need to be adjusted according to season, variety and origin.

In monsoon season if the instances of stem rot are reported, dip cut portion of the stem in 0.2% bavistin and 0.1% streptocycline solution before packing.

If possible, pre-cool to 10 deg C. If packed in crates cover the crates with wet jute pallies. Covering with jute pallies is not required during monsoon season when relative humidity is very high.

PACKING FOR WHOLESALE

8-10 kg in plastic crates or corrugated cartons

Loose curds with leaves without trimming are arranged in the loose trucks and whole truckload is auctioned in mandi for a lump sum amount. Untrimmed curds with leaves can also be sent to mandi tied in thick cotton cloth sheets in nearby mandis, but not fit for long distance travel (beyond 4 hours traveling time

Figure 136: Plastic crates use for cauliflower packaging.

PACKING FOR RETAIL

For supply to supermarkets in ready to retail form single layer packing in plastic crates or corrugated cartons with 2-3 wrapper leaves is most suitable. If required by the buyer wrapping of individual curd in a plastic pouch open from top or shrink wrapping in such a weight that plastic film do not touches the curd surface can also be considered.

IN TRANSPORT:

Use covered tight-packed transport. Cover crates with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings. In case of cartons sufficient air circulation to be ensured. Material should be dispatched as soon as possible. Ideally for wholesale Cauliflower should be harvested in the evening and should be dispatched after sunset so as to reach mandi after midnight.

For distant destination markets and export Cauliflower should be pre-cooled to 10 Deg C and be transported in reefer vehicles with thermostat set at 10 deg C.

Figure 137: Transportation of cauliflower in a small pickup van.

STORAGE

If not for immediate dispatch / distribution store at 2-3 deg C and 90-95% RH.

15.8 Cucumbers

AT FARM

Cucumber can be grown in wide varieties of soils from sandy loam soils to clay soils with good drainage. Make sure the soil contains organic matter by adding organic compost or any Farmyard Manure (FMY) for higher yield. Soil pH between 5.5 and 6.7 is favorable for optimum growth.

The cucumber crop requires a moderately warm temperature and grows best at a temperature between 20-24 Deg C, Japanese long green, Poinsette, straight eight, Pusasanyog and pant kheera (PCUC 28) are the commonly grown varieties in our country. Cucumber seed should be sown during June or January to April.

To produce good quality cucumbers, seeds should be treated with pseudomonas fluorescens @10 gms/kg or Trichoderma Virii @ 4 gms/kg or Carbendazim @ 2gm / kg of seed before sowing and40-50 cartloads/ ha well decomposed FYM should be added at the time of soil preparation. 25 Kg Phosphorus/ha, 50 Kg Nitrogen /ha should be applied. Phosphorus and 25 kg Nitrogen should be given at the time of sowing and 25 kg of Nitrogen should be given after 30 days of sowing.

Cucumber seed is sown by the method of dibbling at a distance of 1.5 m to 2.5 m (row to row) x 60 cm to 90 cm (plant spacing) two to three cucumber seeds should be sown in each pit.

Shallow cultivation may be given during the early stage of cucumber plant growth to control the weeds. Herbicides may also be used for controlling the weeds.

Cucumbers can be harvest after 45 to 60 days from flowering. Cucumbers are harvested at a slightly immature stage, near full size but before seeds fully enlarge and harden. Harvesting is done by hand by cutting free of the vine with a sharp knife, rather than by tearing. Cucumbers should be packed in plastic crates and kept in shade covered with wet hessian sheet or thick cotton sheet.

AT COLLECTION CENTER

Check for quality and size grading, keep in cool place, Small lots brought unsorted by the members, should be sorted graded and packed in corrugated trays or plastic crates with perforated polythene liners and transported to local market in normal trucks at ambient temperature.

For long distance markets and export pre-cool to 10 Deg C and transport in reefer truck thermostat set at 10 Deg. C

PACKING FOR WHOLESALE

10-15 Kg in Corrugated trays / cartons or plastic crates with perforated polythene liner

Figure 138: Wholesale packs of Cucumbers in plastic crates/ corrugated tray

PACKING FOR RETAIL

1-2 Kg Cucumbers may be packed in net bags or shrink wrapped in the thermocol / Plastic/Fiber Tray or in perforated plain or branded polythene pouches. Such retail packs may further be packed in plastic crates or corrugated trays/cartons for transport

Figure 139: Retail packs of sweet corn cobs in polythene pouches/ tray

IN TRANSPORT

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Cucumbers should be pre-cooled to 10-12 Deg C, packed in perforated corrugated cartons or crates with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate sale or distribution, store at 10 to 12 Deg C and 90-95% Relative Humidity. Cucumber can be stored for 7-10 days at max. Cucumbers are highly sensitive to ethylene present in the storage room or in the transport vehicle. Do not mix bananas, melons, tomatoes and other ethylene producing products with cucumber

15.9 French beans

AT FARM

To get uniform size and maturity, use improved varieties preferably fine beans, more even inter-plant spacing and recommended agronomic treatments to give healthy crop. Pick beans every 2 days when they have reached full length, have dark green color and are no longer sticky to touch.

To reduce disease damage soak seeds in 0.2% Ridomil and 0.1% Straptocycline solution as part of pre-germination treatment.

To reduce insect infestations, follow spray recommendations. Be especially observant during pod formation, and monitor crop for eggs of pod borers using 50 plants at random every three days. Timely curative sprays of pyrethroid to coincide with hatching of larvae from eggs.

Harvesting is recommended in the morning and evening hours only. Use smooth surfaced harvesting containers; do not tip from harvest containers. Do not make heap on ground. Sort and grade immediately after harvest to remove defective fruits as per laid down quality standards. Keep in shade covered with wet sacks or jute bag.

AT COLLECTION CENTER

Check for sorting grading. Handle gently at all times, pack in recommended pack. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible.

PACKING FOR WHOLESALE

40 kg in loosely woven Hessian bags lined with perforated poly liner.

PACKING FOR RETAIL

For retail supplies packing in 500 gm perforated poly pouches further packed in branded corrugated trays / cartons may be considered.

Figure 140: French beans in a corrugated box.

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export French beans should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate dispatch / distribution store at 10 deg C and 90-95% RH.

15.10 Green Chili

AT FARM

To minimize variable fruit size, follow fertilizer and irrigation recommendations.

Insect infestation will be controlled by following spray recommendations. To deal with fruit worm, egg monitoring and timely sprays are necessary. Prune out infested fruits early and discard any that comes to maturity.

To combat fruit and stem rot follow recommended seed treatments and nursery procedures. Make high (25 CM) beds in the field and follow recommended spraying and drainage procedures. Treat the seeds with hot water.

Harvest at proper maturity when the fruits are full green and grown to full size on a two to three days cycle. This will reduce problems of red color development

Harvesting is recommended in the morning and evening hours only. Use smooth surfaced harvesting containers; do not tip from harvest containers. Do not make heap on ground. Sort and grade immediately after harvest to remove defective fruits as per laid down quality standards. Keep in shade covered with wet sacks or jute bag.

AT COLLECTION CENTER

Check for sorting grading. Handle gently at all times, pack in recommended pack. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible.

PACKING FOR WHOLESALE

40 kg in loosely woven Hessian bags lined with perforated poly liner.

Fig 141: Green chilli in a gunny bag and in a branded carton

PACKING FOR RETAIL

For retail supplies packing in 250 gm perforated poly pouches further packed in branded corrugated trays / cartons may be considered also can be shrink packed in plastic trays.

Figure 142: Green chilli in a corrugated box and shrink packed in tray

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Green chilies should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate dispatch / distribution store at 10 deg C and 90-95% RH.

15.11 Leafy Vegetables

Spinach

Methi leaves

Bathua

Mustard Leaves

Green onions

Celery

Broccoli

Brussels Sprouts

FARM

The leafy vegetables are represented by the Green onions, Spinach, Methi leaves, Mustard leaves, Coriander Leaves, Mint leaves, Bathu, Chaulai, Cabbage, Broccoli, Brussels sprouts, Celery, Chinese cabbage and other leafy greens.

Most of these vegetables are marketed round the year since they are harvested from one or the other production area of the country at different times. For this reason, no long-term storage is required.

In general, these are characterized as highly perishable with rate of respiration and water loss. All these commodities are damaged easily if subjected to pressure hence should be handled with care

Virtually all leafy vegetables are cut by hand. The determination of harvest maturity varies with commodity, but in general size is the principal criterion. All are harvested in the immature state before the plant has developed to the point of seed production. The older parts of these commodities become fibrous or woody.

Those crops forming a head, such as cabbage, are cut with a sharp knife. Young shoots and leaves are broken off by hand. Celery and green onions are either pulled by hand or dug from the soil. They should be harvested under dry conditions when soil can be readily shaken from the roots. The roots are then trimmed with a sharp knife.

Leafy vegetables should be harvested in cool hours, washed, trimmed, sorted, bunched (where ever applicable) and kept in the shade covered with wet hessian sheet or thick cotton sheet, packed in plastic crates or tied in hessian or thick wet cloth sheet at the farm before transporting to collection center

They must not be exposed to drying winds or they will lose water quickly and become wilted and soft; at the same time there must be enough ventilation to disperse the natural build-up of heat.

Double stage washing is highly beneficial, first wash in potable water to remove soil, dirt and other foreign materials followed by washing in cold chlorinated water, drain properly after washing and before packing in recommended packs

AT COLLECTION CENTER

Check for sorting grading, Bunch size and free moisture, handle gently at all times as leafy vegetables are very sensitive to handling damage/ mechanical injuries. Do not jumble pack in the recommended pack. But arrange properly in the pack and interlayer with newspaper. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible. If pre-cooling facility is available at collection center, pre-cool to 0-2 Deg C and dispatch in reefer trucks. Vacuum and Hydro cooling are the most suitable method for most of the leafy vegetables

PACKING FOR WHOLESALE

5-10 Kg Leafy green vegetables should be packed loosely in Plastic Crates which must not be overfilled, or the produce will be damaged when the containers are stacked.

For local rural markets packaging in traditional containers such as wet cloth sheets, Baskets etc. is likely to remain in use. It is important, however, that containers should not be too large to be carried by one person. Rough handling of heavy packages results in damage to produce. Packaging of leafy vegetables and immature flower heads for urban markets will vary with the type of commodity. The following are examples:

• Cabbages: woven sacks, net bags or field crates of 20-25 kg capacity are suitable.

• Lettuce: one-layer wooden plastic crates or ventilated cardboard boxes each containing 24 heads of lettuce.

• Celery: wooden crates holding 20-30 heads of celery.

• Green onions: normally tied in bunches by the grower; they are best transported in small wooden crates holding 10-15 kg.

• Spinach: crisp, brittle and easily broken by rough handling; Spinach is best packed loosely in cardboard, wooden or plastic field boxes of 5-10 kg capacity; over-packing will cause crushing of leaves and bruising and rapid discoloration of stems.

• Coriander leaves, Mint leaves, Methi leaves and Mustard leaves may be tied in bunches or packed loose; they can be marketed in nets, cardboard or wooden or plastic field crates of 5-10 kg capacity.

PACKING FOR RETAIL

Ready to sell 250-500 gm bunches unwrapped or wrapped in perforated polythene pouches or in shrink wrap. These retail packs may further be re-packed in plastic crates for the purpose of transport

IN TRANSPORT

Leafy vegetables may be transported at ambient temperature covered with wet hessian sheets to achieve evaporative cooling. If available insulated air-cooled vans may also be used

For distant destination markets and export leafy vegetables should be pre-cooled to 0-2 Deg C and be transported in reefer trucks / containers thermostat set at 2 Deg C. Use temperature data loggers to monitor the temperature en-route

STORAGE

If not for immediate dispatch / distribution store at 0-2 Deg C and 90-95% RH

15.12 Okra (Bhindi)

AT FARM

To minimize variation in size pick fruits of required size (average 80 mm length) on every alternate day. If growth is too fast in rainy season daily picking may be considered to achieve some size uniformity. Though Quality specifications allow a wide range (80-110 mm) it is always desirable that a particular container have some size uniformity in order to fetch best price in the whole sale market.

Insect infestation should be controlled by constant crop monitoring and following the proper spraying recommendations given by the plant pathologist. Infested fruits should be pruned out at early stage and any that reaches to full maturity shall be discarded at the time of harvesting itself, as each fruit is harvested individually, and harvester have a good chance to discard it at this stage itself rather than it is sorted out at a later stage which will result in to repeated handling and blackening of edges.

To combat fruit and stem rot, chisel the field before planting and make high (25 cm) beds in the field. Virus damage can only be countered by using resistant varieties and adhering to recommended soil treatment and spray program to control vectors.

Visible seeds can be reduced by avoiding picking fruits that are too big but can only be cured by using varieties free of this character.

To avoid damage to fruits at harvest, use of picking knives is recommended, though initially harvesters face some problems in harvesting with picking knives, once they are used to it, harvesting becomes easy than manual harvesting.

Harvesting should be done in cool hours i.e. in morning and evening only. Harvesting immediately after rains should be avoided.

Use harvesting containers with smooth surface. Sort and Grade immediately into crates in the shade and cover with wet jute sacs / jute palli. Avoid heaping the fruits on ground and do not tip from picking containers.

Disease and Management

(a) Cercospora Leaf Spots:Cercospora malayensis, C. abelmoschi

Symptoms

- In India, two species of Cercospora produce leaf spots in bhendi.
- C. Malayensis causes brown, irregular spots and C.abelmoschi causes sooty black, angular spots.
- Both the leaf spots cause severe defoliation and are common during humid seasons.

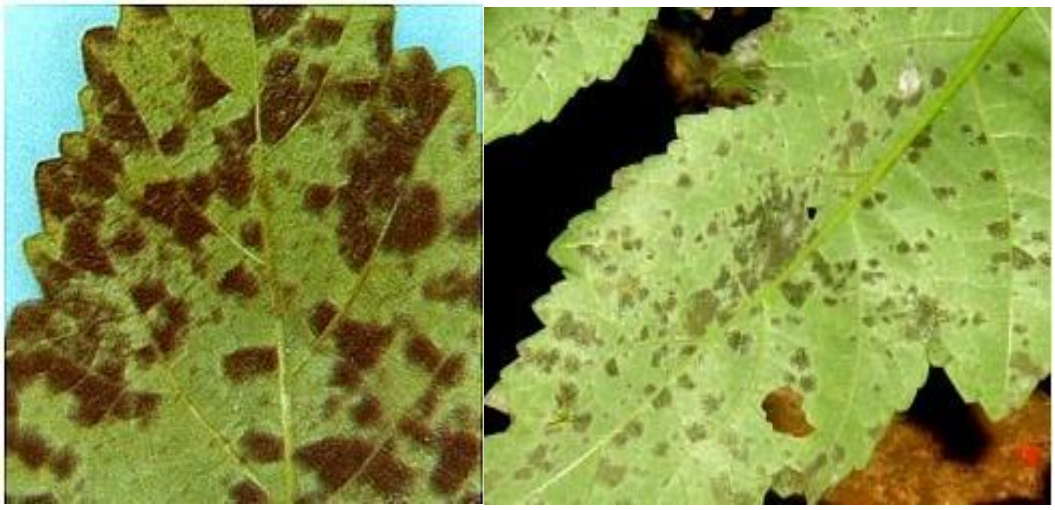


Figure 143 : Cercospora Leaf Spots

Management:

- Spraying Mancozeb 0.25 % control the disease.

(b) Powdery mildew: Erysiphe cichoracearum

Symptoms

- Powdery mildew is very severe on bhendi.
- Greyish powdery growth occurs on the under as well as on the upper surface of the leaf causing severe reduction in fruit yield.

Figure 144: Powdery mildew

Management

- Spray inorganic Sulphur 0.25% or Dinocap 0.1% 3 or 4 times at 15 days interval.

Grading:

S. No	Class	Length (cm)
1.	Small	6 – 8 cm
2.	Medium	9 – 15 cm
3.	Large	16 – 21 cm
4.	Extra Large	More than 22 cm

AT COLLECTION CENTER

Check sorting / grading at collection center, handle gently at all times. Once quality is acceptable, pack in crates / cartons / wet jute sheets, weigh and insert farmer ID. If possible, pre-cool to 10 deg C. If packed in crates cover the crates with wet jute sheets.

Figure 145: Sorting and grading of Okra.

PACKING FOR WHOLESALE

10 kg in plastic crates or corrugated cartons

20 kg in wet jute sheets, thick cotton cloth sheet.

20 kg in loosely woven wet Hessian bags.

Figure 146: wholesale packaging

PACKING FOR RETAIL

1kg net bags further packed in 10 kg crates / 250/500 gm in plastic punnets or branded poly bags.

Figure 147: Packing for Retail

IN TRANSPORT:

Use covered tight-packed transport. Cover crates with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings. In case of cartons, sufficient air circulation to be ensured. Material should be dispatched as soon as possible. Ideally Okra should be harvested in the evening and should be dispatched after sunset so as to reach mandi after midnight.

For distant destination markets Okra should be pre-cooled to 10 Deg C and be transported in reefer vehicles with thermostat set at 10 deg C. To monitor the temperature en-route, Temperature recording data logger should be installed in reefer truck.

STORAGE

If not for immediate dispatch / distribution store at 2-3 deg C and 90-95%

15.13 – ONION / GARLIC

AT FARM

For producing best quality onions and Garlic, good healthy, disease free seed lings grown in a protected nursery shall be planted on raised beds at a uniform plant to plant distance of 6 inches and maintain space between rows at 12 inches.

Seedlings that are about the diameter of a pencil produce the biggest most beautiful bulbs

Onions and Garlic growing require lot of sun and good drainage and grow best when soil pH ranges between 6 to 6.8.

Onion and Garlic roots are shallow and not very efficient at taking up moisture, hence the topsoil should be kept moist consistently until the bulbs enlarged. Mulching with light layer of weed free paddy or wheat straw helps in retaining the topsoil moisture.

Onions and Garlic intended to be sold as green / spring onions or Garlic may be harvested just a few weeks after the planting. There is no perfect size, just pull them when they are grown to size preferred by your market.

For full size bulbs let Onions and Garlic grow and mature, they are ready to harvest when bulbs grow big and the tops begin to turn yellow and fall over. Pull them up, shake off the soil and lay them out to cure with the tops still attached. Any warm airy location is good for curing. They can be cured even by slinging them over a fence as long as they do not become wet by rain. Bulbs must remain dry and have good air circulation

As the onions / Garlic cure, the roots will shrivel and the necks above the bulbs will slowly dry – a natural process that helps to seal the top of the bulb, making the onions/Garlic less likely to rot. After 7 to 10 days, clip off the tops of the onions/Garlic and the roots with pruning shears, remove as much dry dirt as possible without taking off the papery outer skins, and store your onions in a cool place.

Cured Onions shall be sorted to take out defective, diseased bulbs and size graded as per market demand

Figure 148 : Onion cultivation plot

Disease and Management

(a) Basal Rot: Fusarium oxysporum f.sp. cepae

Symptom:

- The leaves turn yellow and then dry up slowly.
- The affected plant shows drying of leaf tip downwards.
- The entire plant shows complete drying of the foliage.
- The bulb of the affected plant shows soft rotting, and the roots get rotted.

- There will be a whitish mouldy growth on the scale.
- This disease can begin in the field and continue in storage.

Figure 149: Basal Rot

Management:

- Growers must follow crop rotation and harvested bulbs must be thoroughly cured to reduce potential storage losses.
- Onions are very sensitive to low soil copper levels. In order to optimize crop production and disease susceptibility, additional soil copper fertility may be needed especially on mucky and sandy soils.
- Soil drenching with Copper oxychloride 0.25 %.

(b) Smut: Urocystis cepulae

Symptom:

- Black smut sori are seen at the base of the leaves and leaf surface.
- Black powdery mass is seen after rupturing of sorus wall.

Figure 150: Smut

Management:

- Seed treatment with Thiram or Captan @ 4g/kg.
- The bulbs may be dipped in Thiram solution 0.25%.

AT COLLECTION CENTER

Onions shall be moved to collection center in loose form only if the collection center is equipped with the sorting, grading and packing line for onions and member farmer is willing to get his potatoes sorted and graded mechanically or in cases where the onions are intended for sale and lot size is small (not truckable). FPO should sort, grade pack and aggregate such lots in to truckable lot and provide market and transport support to willing member farmers

PACKING FOR WHOLESALE

50 kg Hessian bags / loosely woven plastic bags

Figure 151: Bulk pack Onion/Garlic in net bags

PACKING FOR RETAIL

1-5 kg in net packs are suitable. These ready to sell retail packs may further be re-packed in 50 kg Hessian / loosely woven plastic bags or 20 kg in plastic crates

Figure 152: Retail Packs of Onion / Garlic in net bags

IN TRANSPORT

Onions packed in 50 kg Hessian bags / loosely woven plastic bags, can be transported in normal trucks (ambient temperature) with proper aeration for short as well as long distances.

For distant destination markets and export also, Onions can be transported at ambient temperature in normal trucks / containers with proper aeration.

In case of export in reefer containers, Onions can be directly loaded in the pre-cooled containers from the cold store at low temperature and thermostat may be set at 4 Deg C.

STORAGE

If not for immediate dispatch / distribution store at ambient temperature in shade with proper air ventilation, keep on re-shuffling and removing damaged, rotten bulbs at fixed intervals of 15 to 30 days.

Onion storage in ventilation condition is quite satisfactory when the temperature is maintained between 25oC to 30 Deg C with a relative humidity range of 60% to 65%. This environment reduces the storage losses, which are in the form of physiological loss in weight, rotting and sprouting.

Though not many cold stores are available for storage of onions in our country, onions can be stored at low temperature of 2-4 Deg C and 60-65% RH up to 10 months without any deterioration, however ventilation is vital in storage of onions. After storing, onions are not transported straight from the cold storage to the market. Temperature should be raised @ 1 Deg C per day till 25 Deg C with high velocity air circulation to drive off the moisture generated during warming. Onions shall be withdrawn from temperature-controlled chambers only when they reach near to ambient temperature so that no moisture condensation takes place upon the surface of onion bulbs.

Figure 153: Traditional Onion Storage

Figure 154: NHRDF improvised structures

Salient features of improved ventilated storage structures

- ✓ Construction of structure on raised platform to prevent moisture contact and dampness.
- ✓ Use of Mangalore tiled roof or other suitable material to prevent build-up, high temperature inside.
- ✓ Providing bottom ventilation for free and faster air circulation to avoid formation of hot and humid pockets between the onion layers.

- ✓ Avoid direct sunlight on onion bulbs to reduce sunscald, fading of color and quality deterioration restriction on width of each stack to 60-75 cm for hot and humid weather, 75 - 90 cm for mild and humid weather and 90-120 cm for mild and dry weather conditions.

- ✓ Maintenance of stacking height to 100 cm for small and multiplier onions and hot weather and 120 cm for mild weather and for big onions to avoid pressure bruising providing cubicles instead of continuous stack and sufficient space for ventilation from all sides.

One cubic meter area of store accommodates about 750 kg onions. Accordingly, construction of godown for required capacity and construction of more units instead of single big structure and in zigzag manner when constructed in more rows to have better aeration providing 2-tier if space available is insufficient.

15.14 Potato

AT FARM

Size uniformity and quality of tubers can only be achieved through sowing improved varieties, using wide bed technology combined with seed treatment, equal inter-plant spacing, and recommended fertilizer and drainage practices, etc.

Leveling off the field and proper drainage contributes about 10% increase in the yield of the potato with quality enhancement

Weed management and proper earthing to cover the seed fully results into reduction in green potatoes.

Integrated pest management reduces the chances of early and late blight and other viral, fungal and bacterial diseases

Potatoes are harvested at different stages of maturity, for fresh consumption potatoes can be harvested when the haulms are still green because this is the stage when tubers are not fully matured. These

potatoes have short shelf life hence should be packed in hessian bags immediately after harvesting and sent to the market for sale

If the harvesting is done for the matured potatoes, then the irrigation should be stopped before 20 days of harvesting. Harvesting may be done either by the tractor driven digger, Potatoes intended for immediate consumption / sale shall be sorted graded, packed in 50 kg Hessian bags and dispatched to the market.

Potatoes intended for long storage shall be properly cured in the field itself by keeping in heaps covered with the paddy or wheat straw for about 7-10 days. Potatoes shall be sorted to remove the defective and diseased tubers and should be size graded manually or with the help of mechanical grader, packed in 50 kg hessian bags or loosely woven plastic bags and shall be dispatched to the cold store

If not cured in field shall be stored at 15 Deg C in cold store for 10 days before lowering the temperature.

Disease and management

(a) Late blight of potato: Phytopthora infestans

Symptom:

- It affects leaves, stems, and tubers.
- Water-soaked spots appear on leaves, increase in size, turn purple, brown& finally black colour
- White growth develops on under surface of leaves.
- This spreads to petioles, rachis& stems.
- It frequently develops at nodes.
- Stem breaks at these points and the plant topples over. In tubers, purplish brown spots and spread to the entire surface on cutting, the affected tuber show rusty brown necrosis spreading from surface to the center.

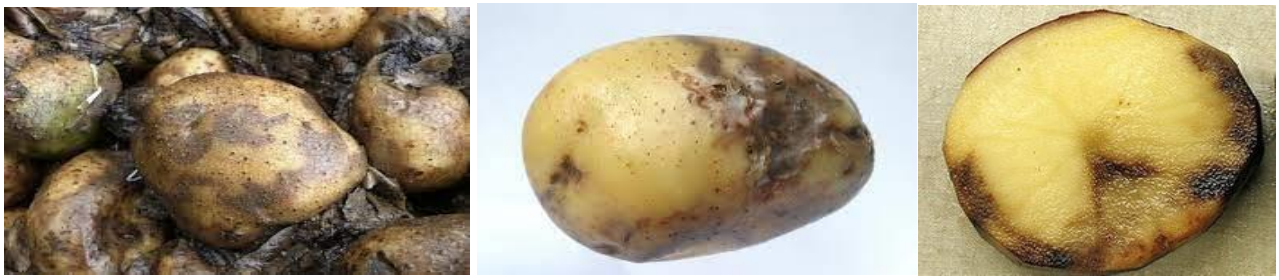


Figure 155: Late blight of potato

Management:

- Protective spraying with mancozeb or zineb 0.2 % should be done to prevent infection of tubers.
- Tuber contamination is minimized if injuries are avoided at harvest time and storing of visibly infected tubers before storage.
- The resistant varities recommended for cultivation are Kufri Naveen, Kufri Jeevan, Kufri Alenkar, Kufri Khasi Garo and Kufri Moti.
- Destruction of the foliage few days before harvest is beneficial and this is accomplished by spraying with suitable herbicide.

AT COLLECTION CENTER

Potatoes shall be moved to collection center only if the collection center is equipped with the sorting, grading and packing line for potatoes and member farmer is willing to get his potatoes sorted and graded mechanically or in cases where the potatoes are intended for sale and lot size is small (not truckable). FPO should sort, grade pack and aggregate such lots in to truckable lot and provide market and transport support to willing member farmers

PACKING FOR WHOLESALE:

Potatoes for wholesale can be packed in 50 kg hessian /Jute / loosely woven plastic bags. Loosely woven plastic bags are most suitable for potatoes intended for storage.

50 Kg loosely woven plastic bags

For retail supply 1 – 2 kg Potatoes may be packed in net bags clipped

PACKING FOR RETAIL

For retail supply 1 – 2 kg Potatoes may be packed in net bags clipped at both ends with a SS clip. Retail packs may be further packed in crates or loosely woven plastic or Hessian bags for transport.

Figure 156: packaging for retail

IN TRANSPORT

Potatoes packed in 50 kg Hessian bags / loosely woven plastic bags, can be transported in normal trucks (ambient temperature) for short to medium distances (Up to 3 days at max) with proper aeration.

For distant destination markets and export Potatoes should be loaded directly in the reefer containers / trucks from the cold store. Temperature of reefer container / truck with thermostat should be set at 4 Deg C for potatoes stored at low temperature (2-4 Deg C) and at 10 Dg C for Potatoes stored at High Temp (10 Deg C) under CIPC application. Use temperature data logger in reefer truck to monitor en-route temperature

STORAGE

If not for immediate dispatch / distribution store at 4 deg C and 90-95% RH, however at this temperature Potatoes become sweet at the time of withdrawal due to conversion of starch in sugars. Hence not liked by the consumers

Alternatively, Potatoes can be stored at 10 Deg C with CIPC application to avoid sprouting. These Potatoes are marketed as low sugar potatoes in the market and fetch better price realization then potatoes stored at low temperature.

15.15 Radish

White Radish

Red Radish

AT FARM

Uniform roots can only be achieved through sowing improved varieties, equidistant sowing, thinning, and following recommendations for soil selection, ridging, fertilizer and drainage, etc. This will also reduce mis-shaped and forked roots, green top, natural growth cracks, root scab and secondary roots.

Problem of Green top will be reduced by sowing at correct depth and by following recommended irrigation and drainage methods.

Rough, coarse roots can be reduced by better soil selection.

Root nodes and secondary roots can be controlled by selecting soils free from nematodes and using Furadan or phorate.

Black top and black rings on roots occur mainly in the monsoon. They are controlled by following land selection, ridging, fertilizer and drainage recommendations. Follow spray recommendations and spray heavily or drench with 0.2% Ridomil if black top or black rings are seen.

Insect infestation and fungal infection of the leaves will be controlled by following spray recommendations. Pruning the damaged leaves at early stage. Discard any such leaves that attached to the root after harvesting. Sort out to remove defective roots. Trim the yellow leaves, insect infested leaves if any attached to roots. In case of excess leaves trim some outer roots to ensure approximately 1: 1 root leaf ratio.

Wash the roots immediately after harvesting and sorting. Do not keep in sun. Allow proper drainage of the excess water before sorting and packing into crates or tying in sheets. Keep covered with wet jute sacs or sheets after washing and during transport.

Harvest at full maturity but does not delay to try and gain weight, as this will lead to oversized and hard tasteless roots.

Harvesting is recommended in the morning and evening hours only. Radish can be dispatched twice, morning harvest for afternoon sales and evening harvest for early morning sale in mandis.

AT COLLECTION CENTER

Check for sorting grading, pack 10 kg in crates, or 40 kg in wet jute sheets / thick cotton sheets. Branded corrugated trays can also be used if economically feasible. Dispatch as early as possible so as to reach mandi for morning or afternoon sale.

PACKING FOR WHOLESALE

Traditionally 35-40 kg Radishes are being packed in wet jute sheet or thick cotton cloth sheet and auctioned by the pack. Both washed and unwashed radishes are being sent to mandi for sale by farmers almost in equal proportions.

Radish being a low-priced item, wholesale packing is recommended similar that of traditional to be price competitive.

PACKING FOR RETAIL

For retail supplies packing 10 kg radishes in plastic crates or branded corrugated trays can be considered. Ready to retail packing of 1 kg radishes with around 4-inch leaves (rest of leaves trimmed) in polythene pouches can also be considered.

Figure 157: White radish being transported through plastic crates

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Radish should be pre-cooled to 4 Deg C and be transported in reefer vehicles with thermostat set at 4 deg C.

STORAGE

If not for immediate dispatch / distribution store at 2-3 deg C and 90-95% RH.

15.16 Round Gourd (TINDA)

AT FARM

To minimize variable fruit size, follow fertilizer and irrigation recommendations. Pick at 2 days intervals to required size. Improve pollination by using bees

Growing on trellis will reduce the problem of light-colored fruit bases / white patches on the fruit where it touches the ground.

Insect infestation will be controlled by following spray recommendations and pruning the infested fruits at early stage and discard any that comes to maturity.

To combat Anthracnose spotting make high (25 CM) beds in the field and follow recommended spraying and drainage procedures, etc. Disease incidences will be less if Round gourd is grown on trellis because of better ventilation and greater accessibility for spraying.

Harvest at proper maturity when the fruits are tender. Does not delay to try and gain weight, as this will lead to oversized, mature fruits with large and harder seeds.

Harvesting is recommended in the morning and evening hours only. Use smooth surfaced harvesting containers; do not tip from harvest containers. Do not make heap on ground. Sort and grade immediately after harvest to remove defective fruits as per laid down quality standards. Keep in shade.

AT COLLECTION CENTER

Check for sorting grading and tenderness. Handle gently at all times as the skin of tender Round gourd have very fine hair like structures and is very sensitive to bruises and any bruising will not show up immediately but will appear as brown / black patches after 3-4 hours of injury. Do not jumble pack in the recommended pack. But arrange properly in the pack and interlayer with newspaper. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible.

PACKING FOR WHOLESALE

30-40 kg in loosely woven Hessian Bags lined with perforated poly liner or 10-12 kg in crates or corrugated trays / cartons interlayer with newspaper.

Figure 158: Tinda in loosely woven perforated poly liner

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PACKING FOR RETAIL

For retail supplies packing 10 kg Round gourds in plastic crates or branded corrugated trays can be considered. Ready to retail packing of approx. 500 gm and 1 kg Round gourd in perforated polythene pouches can also be considered further packed in crates or branded corrugated trays.

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Round gourd should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate dispatch / distribution store at 10 deg C and 90-95% RH.

15.17 Sponge Gourd (TORI)

AT FARM

To minimize variable fruit size, follow fertilizer and irrigation recommendations. Pick at 2 days intervals to required size. Improve pollination by using bees

Insect infestation will be controlled by following spray recommendations and pruning the infested fruits at early stage and discard any that comes to maturity.

To combat diseases, make high (25 CM) beds in the field and follow recommended spraying and drainage procedures, etc. Disease incidences will be less if Sponge gourd is grown on trellis because of better ventilation and greater accessibility for spraying.

Harvest at proper maturity when the fruits are tender. Does not delay to try and gain weight, as this will lead to oversized, mature Sponge gourd with large and harder seeds.

Harvesting is recommended in the morning and evening hours only. Use smooth surfaced harvesting containers; do not tip from harvest containers. Do not make heap on ground. Sort and grade immediately after harvest to remove defective fruits as per laid down quality standards.

AT COLLECTION CENTER

Check for sorting grading, handle gently at all times as the skin of sponge gourd is very sensitive to bruises and any bruising will not show up immediately but will appear as brown / black patches after 3-4 hours of injury. Do not jumble pack in the recommended pack. But arrange properly in the pack and interlayer with newspaper. Insert farmer ID. Keep in cool place, do not keep in sun. Dispatch as early as possible.

PACKING FOR WHOLESALE

30-40 kg well arranged in a bamboo basket lined with smooth cloth or 10-12 kg in crates or corrugated trays / cartons interlayer with newspaper.

Figure 159: Sponge gourd in a corrugated box.

PACKING FOR RETAIL

For retail supplies packing 10 kg Sponge gourds in plastic crates or branded corrugated trays can be considered. Ready to retail packing of approx. 500 gm and 1 kg bitter gourd in perforated polythene pouches can also be considered further packed in crates or branded corrugated trays.

IN TRANSPORT:

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or pallies to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Sponge gourd should be pre-cooled to 10 Deg C, packed in perforated corrugated cartons with perforated poly liners and be transported in reefer vehicles with thermostat set at 10 deg C.

STORAGE

If not for immediate dispatch / distribution store at 10 deg C and 90-95% RH.

15.18 Sweet Corn



AT FARM

Both white and yellow grain types of sweet corn are grown in our country. bicolor corn (yellow and white) can also be produced by Cross-pollination of yellow kernel varieties with white kernel varieties. Some of the recommended sweet corn varieties released for cultivation in India are Madhuri, Priya and Almira sweet corn.

To produce high quality sweet corn new seed should be used each year as seed quality (velour) gets reduced substantially within a year, especially in the case of super sweets. Recommended plant population for optimum yield is 45000-60000 plants per hectare with row spacing of 75-100 cm and intra rows pacing of 15-30 cm.

Sweet Corn may be grown in all types of soil and is moderately salt-tolerant. However, it grows well in well-drained soils with pH of 5.5-7.0.

Usually Sweet Corn is propagated through seeds and is seldom transplanted in special cases. Seed treatment with Imidacloprid 70WS @ 5g/Kg takes care of insect pests and fungicide treatment helps to prevent the attack of damping-off

Fertilizer must be applied according to soil test results. A general recommendation would be to apply a total of 100-120 Kg of nitrogen, 50-60 Kg of phosphate (P205) and 40-60 Kg potash (K20) per ha.

The crop should remain weed-free during the early stages of plant growth; otherwise, yields might be substantially reduced

Harvesting maturity: Sweet corn ears are generally ready for harvest approximately three weeks after the first silk emergency, depending on the temperature. Silk will start to turn brown about two weeks after emergence. Ears should be harvested when the kernels appear to be milky when punctured with a thumbnail. It is called the milky stage.

Harvesting method and field assembly: Ears of standard varieties will remain in prime condition for only a short time in warm weather when compared to cool weather. Harvest in the early morning when both the ears and the weather are cool. When harvesting, break the stem of the ear as close to the ear as possible without breaking the main stalk.

Harvested ears should be cooled to 0˚ C within 4 hours of harvesting. Use field plastic or wooden crates to handle the corn.

If corn cannot be refrigerated immediately, it should be stored in the shade to reduce heating from the sun. When harvesting for direct market supply, harvest only one-day supply and keep as cool as possible. Ears can be packed in field-crates topped with ice, and kept at 0 Deg C. Ears, in these conditions will be marketable for 5 to 10 days.

AT COLLECTION CENTER

Check for quality and sweetness (TSS), keep in cool place, Small lots brought unsorted by the members, should be sorted graded and packed in plastic crates preferably with perforated polythene liners and transport to local market in normal trucks at ambient temperature.

For long distance transport and export pre-cool to 0-2 Deg C and transport in reefer trucks/containers thermostat set at 2 Deg C to avoid freezing.

PACKING FOR WHOLESALE

5-10 Kg in Corrugated trays / cartons or plastic crates with perforated polythene liner.

Figure 160 Wholesale packs of sweet corn cobs in corrugated tray / plastic crates

PACKING FOR RETAIL

Shrink wrap 2-8 Cobs in thermocol / Plastic/Fiber Tray or in perforated plain or branded polythene pouches. Such retail packs may further be packed in plastic crates or corrugated trays/cartons for transport

Figure 161: Retail packs of sweet corn cobs in tray / polythene pouches

IN TRANSPORT

Use covered tight-packed transport. If packed in crates, keep covered with wet jute sacks or sheets to achieve evaporative cooling and high humidity in surroundings.

For distant destination markets and export Sweet Corn Cobs should be pre-cooled to 0-2 Deg C, packed in perforated corrugated cartons or crates with perforated poly liners and be transported in reefer vehicles with thermostat set at 2 deg C.

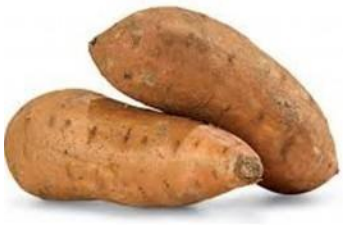
STORAGE

If not for immediate sale / distribution store at 0-2 Deg C

Traditionally sweet corn varieties are seldom stored for more than a few days, because of the resulting serious deterioration and loss of tenderness and sweetness. The loss of sugar (which is converted to starch) fastens with the increase of temperature. Prompt cooling at 0 Deg C and high Relative Humidity will extend shelf-life.

15.19 Sweet Potato





AT FARM

Sweet Potato can be grown in wide varieties of soils ranging from sandy to loamy soil, but it gives best results when grown under sandy loam soil having high fertility and good drainage system. Soil pH between 5.8 to 8.7 is best suited to sweet potato cultivation.

The Sweet Potato crop requires a moderately warm temperature and grows best at 21-26 Deg C, generally sweet potato varieties differ in size shape, color of skin and tuber flesh.

Important high yielding varieties include Varsha, Sree Nandini, SreeVardhini, SreeRatna, Cross 4, Kalmegh, Rajendra Shakarkand-5, Sree Varun, Sree Arun, sreebhadra, Pusa Safed and PusaSunahari.

For optimum yield tubers should be sown in nursery beds in the month of January to February and the optimum time for planting vines in the field is in the month of April to July.

30 Kg / acre Nitrogen, 20 kg / acre Potash and 25 kg / acre Phosphorus should be applied. Apply Metribuzine 70 WP @ 200gm per acre or Aalchlor @ 2 ltr per acre before sprouts emerge and again on emergence of 5-10% sprouts. If ridges are infested with weeds, then apply Paraquat @ 500-750 ml per acre.

Mainly propagation is done by tubers or vine cuttings. In vine cutting method (commonly used), the tubers are taken from the old vines and planted on prepared nursery beds. Generally, vines are planted in ridges or on prepared flat beds. Row spacing of 60 cm and within row spacing of 30 cm is used.

Sweet potatoes are considered ready for harvest when the leaves begin to yellow. A further test of readiness to harvest is said to be that of cutting mature tubers the cut surfaces do not discolor.

Harvesting is carried out either progressively or all at one time. Sweet potato crops grown on a commercial scale are usually harvested all at one time.

Great care must be taken to avoid damage to the skin of sweet potato roots during harvesting, since they are very prone to post-harvest decay under tropical conditions. Harvested roots should be collected in baskets, boxes or crates in which they can remain throughout their post-harvest life without disturbance, through curing and storage if necessary.

Harvested tubers should be cured for 7-10 days at around 27-34 Deg C and 85-90% RH. Curing is a process of healing by the formation of new skin on damaged areas of sweet potatoes, and also of the maturing and hardening of the whole skin of the roots.

Disease and management:

(a) Rot: Ceratocystis fimbriata

Symptoms:

- Small, circular, slightly sunken, dark brown spots are the initial symptoms of black rot.
- Spots enlarge and appear greenish black to black when wet and grayish black when dry. Within the spots are small, black fungal structures (perithecia) with long necks which appear to the naked eye as dark bristles. The rot usually remains firm and shallow.
- If secondary fungi or bacteria invade the tissue however, the flesh beneath the spot turns black, and this blackened area may extend to the center of the root.
- Tissue near the discolored area may have a bitter taste. Eventually, the entire root may rot. Roots may appear healthy at harvest but rot in storage, during transit, or in the market.

Figure 162 : Rot

Management

- Control black rot with crop rotation, since most crops are unaffected by the disease.
- Disinfect seedbeds if a clean site is unavailable.
- Propagate plants from healthy stem cuttings.
- Cure roots immediately after harvest. (Cure roots at 85 to 95 degrees F and 85 to 90 percent relative humidity for 5 to 10 days.)
- Apply a postharvest fungicide.
- Do not wash and package roots showing symptoms of black rot.
- Decontaminate equipment that comes into contact with an infected crop.
- Spray empty washing machines and crates with a fungicide.
- Fumigate storage structures.

(b) Rhizophus soft rot: Rhizopus stolonifer

Symptoms

- Infection and decay commonly occur at one or both ends of the root, although infection occasionally begins elsewhere.
- Rotting may be inhibited under dry conditions, but under humid conditions the affected sweet potatoes become soft and watery, and the entire root rots within a few days.
- If the humidity is high, the sweet potatoes become heavily "whiskered" with a grayish black fungal growth. This feature distinguishes Rhizopus soft rot from other storage rots.
- The color of the root is not significantly altered, but an odor is produced that attracts fruit flies to the area.
- Infection is especially likely if the relative humidity is between 75 and 85 percent during storage or transport. Also, the longer roots are stored, the more susceptible they become.
- Chilling and heat damage also predispose sweet potatoes to infection. Soft rot is very destructive when sweet potatoes are washed, packed, or shipped to market during cold weather.

Figure 163: Rhizophus soft rot:

Management

- Carefully handle sweet potatoes during harvest to prevent unnecessary wounding. This is the most important control method for soft rot.
- Properly cure roots immediately after harvest.
- Store roots at 55 to 60 degrees F.

Avoid handling stored roots because handling can create new wounds. Recuring is one possible solution to this problem.

Apply a recommended fungicide after harvest.

Do not allow sweet potatoes to be exposed to sunlight for extended periods (to prevent heat damage) or to be chilled in the field.

AT COLLECTION CENTER

Check for quality and size grading, ensure that roots are properly cured, and defective or diseased roots are removed. Keep in shade preferably in plastic crates or loosely woven plastic bags. Avoid packaging of sweet corn in gunny bags if possible.

PACKING FOR WHOLESALE

Sweet Potato for wholesale can be packed in loosely woven plastic bags, Plastic Crates, corrugated cartons etc. If possible, jute bags should avoid for long distances as it may cause damage to skin of the tubers.

PACKING FOR RETAIL

1-2 kg sweet potato could be packed in net bags for retail. Such ready to sell packs may further be packed in 20 kg plastic crates or loosely woven plastic bags for transport.

IN TRANSPORT

Sweet Potatoes packed in 50 kg loosely woven plastic bags, or 20 kg in plastic crates can be transported in normal trucks (ambient temperature) for short to medium distances (Up to 3 days at max) with proper aeration.

For distant destination markets and export Sweet Potatoes should be loaded directly in the reefer containers / trucks from the cold store. Temperature of reefer container / truck with thermostat should be set at 10-12 Deg C

STORAGE

Sweet potatoes are subject to very rapid deterioration after harvest at ambient tropical temperatures. However sweet potatoes can be stored at 10-15 Deg C and 85-90% RH. Care should be taken as they are prone to chilling injuries below 10 Deg C.

• The roots must be fully mature and well cured before storage;

• They must be handled carefully at all times and only sound roots should be stored;

15.20 TOMATOES

Tomato Desi

Cherry Tomatoes

Tomato Bombay (Hybrid)

AT FARM

Tomato grows very well on a wide range of soils, but it grows well on deep, well-drained soils with good drainage ability. Sandy loam to medium black soils having pH in the range of 6-7 is considered to be best suitable for Tomato cultivation.

To produce high quality tomatoes good healthy, disease free seed lings grown in a protected nursery shall be planted

At the time of land preparation, apply well-decomposed FYM at 20 to 25 t/ha in the soil. Then add a basal fertilizer dose Nitrogen – 60 kg, Phosphorus – 80 kg and Potash -60 kg per hectare. After 30 to 45 days of planting, give 30 kg amount of nitrogen to the crop.

Before transplanting plant in the field treat with a fungicide like Bavistin and humic acid.

The long growing varieties of tomatoes need to be specially supported. At the time of plant growth, plants should be staking with the help of string or wire.

With the help of this support, fruits cannot expose to soil and water; hence there is no problem of tomato fruit rotting so that more production can be obtained.

Always maintain clean and weed free farm because weed competes with crop also, they provide shelter to the various harmful insect. Mulching using 50-micron black plastic sheet controls about 95% weeds. Alternatively, one can use organic mulch like sugar cane trash, which controls about 60% of weeds.

Harvesting maturity. Tomato fruit stalks have a natural breakpoint. Mature fruit readily breaks away from the cluster when pressure is placed on this point while lifting the fruit upwards. Tomato fruits should be harvested at following stages of maturity depending upon the distance to the market and transport mode

a) Breakers stage: Tomato fruit for intended for long distant market shall be harvested at breakers stage i.e. when color break is observed at blossom end.

b) pink stage: The tomato intended for sale in nearby markets should be harvested upon change of color from green to pink

c) Maturity stage: Tomato for the local market shall be harvested after the fruit turns reddish on the plant.

d) Full maturity: Tomato intended for supply to processors shall be harvested upon full maturity i.e. when fruit is fully reddish and slightly red on the tree. Such fruits are useful to make durable materials such as ketchup, sauce, soup, chutney, etc.

Harvested tomatoes should be sorted to remove defective and diseased fruits and size graded as per market demand and packed in plastic crates holding not more than 20 to 25 kg weight.



Nursery raising to produce tomato seedlings Figure xxx cultivation on trellis

AT COLLECTION CENTER

Check for Selection and grading; ensure that all decaying, damaged, undersized and sunburned fruits are discarded. Also check for size grading, Size-graded Tomatoes generally fetch better price. Tomatoes can be brought in unsorted form if collection center is equipped with a sorting grading line for tomatoes. Otherwise collection center can sort grade aggregate smaller lots in to truckable lots and provide transport and marketing support to member farmers. Truckable lots can be moved directly from field to market or processing center

PACKING FOR WHOLESALE

For local markets tomatoes can be packed in baskets or other traditional containers assuring careful handling, i.e. rigid enough to protect the contents from being crushed.

For urban markets corrugated trays, wooden Boxes or plastic crates with capacities of not more than 20 kg, should be used. Size-graded tomatoes can be pattern-packed in 2 layers i.e. lower layer of for reddish green produce and upper layer of ripe red produce to make best use of the box. Un-graded tomatoes are jumble-packed to a given weight.


Figure 164: Wholesale packing of tomatoes in corrugated trays and crates

PACKING FOR RETAIL

Ready to sell 1-2 kg in net packs are suitable. These retail packs may further be re-packed in plastic crates for the purpose of transport

Figure 165: small scale Net Packing Machine

Figure 166: Tomatoes packed in transparent net bags

IN TRANSPORT

Tomatoes packed in 20 kg plastic crates, can be transported in normal trucks (ambient temperature) with proper aeration for short as well as medium distances (up to 3 days at max)

For distant destination markets and export Tomatoes should be pre-cooled to 10 Deg C and be transported in reefer trucks / containers thermostat set at 10 deg C

STORAGE

Tomatoes have a relatively poor storage capability. Green mature fruit can be held for up to two weeks at 18-20 o C and 90-95% Relative Humidity, but for less time under ambient tropical temperatures. Fully ripe tomatoes have only 4 to 7 days' storage life, at 10-15 Deg C and 90-95% Relative Humidity.

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