

## **SECTION 3**



# **HARVEST AND POST HARVEST TECHNOLOGIES**

## Session 3.1 Harvest technologies

### Key learning points



- Picking periods, calendars and maturity indices
- Picking Procedures
- Field trimming, cleaning, grading and packing
- Harvest containers
- Mechanisation and produce damage
- Field heat and cooling techniques and equipment
- Field curing

### Main objectives of the session

By the end of the session participants will be better able to:



- Harvest a good quality crop in good condition and at the right time
- Measure crop maturity
- Harvest fruit and vegetables without damage
- Effectively trim, clean, grade and pack produce in the field
- Select the most appropriate harvest containers and technologies
- Effectively remove field heat
- Cure root and bulb crops

### 3.1.1 Picking periods, calendars and maturity indices

The timing, technique and conditions at harvesting can significantly prices. The planning and implementation of harvesting operations must follow basic principles, whatever the cultivation system used or the labour and equipment available. The objectives must be:

- ❑ To harvest a good quality crop in a good condition
- ❑ To keep the harvested produce in good condition until it is consumed or sold
- ❑ To sell the crop at the best possible price

With some crops, harvesting can be undertaken early to take advantage of high priced opportunities e.g. cabbage harvested as spring greens, young carrots sold in bunches, green plums and new potatoes. Exploiting these short-term market opportunities requires a close link with the market.

To meet these objectives, success in harvesting and marketing depends on planning from the earliest stages of production, particularly in regard to:

- ❑ Crop selection and timing in order to meet expected market requirements
- ❑ Maintaining contacts with buyers and receiving information on markets so that the crop can be sold at a good price when it is ready for harvest
- ❑ Planning harvest operations in good time and in particular arranging adequate labour, equipment and transport
- ❑ Providing proper supervision at all stages of harvesting and field handling

When the crop is ready for harvest, labour and transport are available and harvesting plans are ready, the final decision to start harvesting will depend largely on, weather conditions and the state of the market.

Flexibility in harvesting will depend on the crop. Some, such as root crops, can be harvested and sold over a long period, or stored on the farm to await favourable prices. Others, such as soft berry fruits, must be marketed as soon as they are ready or they will spoil.

When the decision to harvest has been made, the best time of day for harvesting must be considered. The aim being to dispatch the produce to market in the best possible condition, that is, as cool as possible, properly packed and free from damage.

The basic rules for picking are:

- ❑ To harvest during the coolest part of the day, i.e. early morning or late afternoon and the plant has its highest moisture content
- ❑ Not to harvest during high temperatures because the intense plant transpiration causes increasing losses of water, mainly in herbaceous products
- ❑ Not to harvest produce when it is wet from dew or rain, because wet produce will overheat if it is not well ventilated, and it will be more likely to decay. Some produce may be more subject to damage when wet such as oil spotting and rind breakdown in some citrus fruits

- ❑ To protect harvested produce in the field by putting it in the shade when transport is not immediately available. Produce left exposed to direct sunlight will get very hot and deteriorate.

In practice other criteria also have to be taken into account. Harvesting has to take into account labour availability and when collection will take place, to minimise the time produce is left standing in the field. Produce for local markets can easily be harvested early in the morning and delivered the same day. For more distant markets it may be an advantage (if suitable transport can be arranged) to harvest in the late afternoon and transport to market at night or early the next morning.

Shelf life and long term storage is affected by the maturity of the crop at harvest. Fruit and vegetable maturity is characterised by a series of profound changes, many of which are visible, mainly regarding the change of colour and some of which are not. A fruit is mature when the growth processes have terminated and the stage of decay is not yet predominant. At this point the substances that are stored should guarantee the highest degree of flavour and good preservation. After changes in the colour there is normally a softening of the pulp and a change in flavour due to an increase in sugars.

Maturity can be measured with the indexes used during harvest and which include:

- ❑ The basic colour of the outer skin
- ❑ The firmness of the pulp
- ❑ The refractometric residue
- ❑ Total acidity levels
- ❑ The size of the fruit
- ❑ Respiratory activity
- ❑ The ethylene content;
- ❑ The Streif index

The *basic colour* serves to identify the green portion of a fruit. This is assessed by using colour charts or, more accurately, with an optical reading machine. The *firmness of the pulp* is evaluated with a penetrometer, which comprises of a piston and calibration spring connected to a pointer moving across a graduated scale. The *refractometric residue* assesses the percentage of soluble solids that are contained in the juice that is extracted from the fruit. The *total acidity* is determined by titration with sodium hydroxide (NaOH) of the total free acids. The *size of the fruit* provides an evaluation criterion particularly for vegetables at the time of harvest (such as, cabbage, broccoli and lettuce). The *respiratory activity* is an index used for fruits (such as, apples, pears and bananas) that must be harvested before reaching their respiratory peak. The *ethylene content* in the tissues of many fruits and vegetables is strictly correlated to maturity and the length of preservation. The *Streif index* is considered one of the most accurate methods for determining optimal maturity and is calculated using the following formula:

$F/RS$ , where F is the pulp firmness expressed in kg, R is the refractometric residue in °Brix and S is the % quantity of starch. The index is measured on a scale from 1 to 10.

Maximum maturity standards at which crops are ideal for picking have been determined for many fruit, vegetables and flowers. Harvesting crops at proper maturity allows handlers to begin their work with the best possible quality produce. Produce harvested too early may lack flavour and may not ripen properly, while produce harvested too late

may be fibrous or overripe. It is important to identify produce that is ready for harvest. Vegetables in particular can be harvested over a wide range of maturities and depending on the market to which it is to be sold e.g. fresh, canned or processed.

For example, apples for long term storage should be picked when fully mature but not fully ripe, cabbages for fresh markets should take place after the head has formed tightly and before the outer leaves start to die or the head shows any sign of splitting. At the correct stage of maturity freshly harvested cabbage heads should squeak when rubbed together. Timing is also crucial for the harvest of quality melons – too early and the full sugar content is not developed, too late and they lose sugar and become soft. Canteloupe melons should be harvested when the fruit separates easily from the plant. If only part of the stem pulls off then the fruit is not ripe and will never ripen to full flavour. A honeydew melon is ready for harvest when the fruit is well filled out, there is just a hint of green and the surface is covered with fine hairs. Watermelons should be harvested when the ground spot is pale yellow and the fruit gives a hollow sound when hit with the knuckle.

Some fruit have to be harvested when they are not completely ripe in order to transport them to distant markets. This is particularly true of fruits that are not suitable for long term storage but need their shelf life maximised. The optimum harvesting stage for most crops will depend not only on the climate and distance to the market but also on variety and growing conditions. In individual cases, when new distances markets are being explored, experiments should be carried out to find the best stage to harvest fruits, by sending samples at different degrees of ripeness and assessing which is most favoured.

The following table provides general guidance using maturity indices and picking specifications for selected fruit and vegetables:

**TABLE: Maturity indices and picking specifications for selected fruit and vegetables**

Index	Selected Fruit
Elapsed days from full bloom to harvest	Apples, pears
Average heat levels during development	Peas, apples, sweet corn
Development of abscission layer	Some melons, apples,
Surface shape and structure	Cuticle formation on grapes, tomatoes Netting of some melons Gloss of some fruits (development of wax)
Size	All fruits and many vegetables
Specific gravity	Cherries, watermelons, potatoes
Shape	Angularity of banana fingers Full cheeks of mangos

	Compactness of broccoli and cauliflower
Solidity	Lettuce, cabbage, brussel sprouts
<b>Textural properties</b>	
Firmness	Apples, pears, stone fruits
Tenderness	Peas
External Colour	All fruits and most vegetables
Internal colour and structure	Formation of jelly-like material in tomato fruits Flesh colour of some fruits
<b>Compositional factors</b>	
Starch content	Apples, pears
Sugar content	Apples, pears, stone fruits, grapes
Acid content, sugar/acid ratio	Pomegranates, citrus, papaya, melons, kiwifruit
Juice content	Citrus fruits
Oil content	Avocados
Tannin content	Persimmons, dates
Internal ethylene concentration	Apples, pears
<b>Specific crops</b>	
Large enough and crispy (over mature if pithy)	Radish and carrot
Tops beginning to dry out and topple down	Potato, onion, and garlic
Leaves at their broadest and longest	Green onion
Well-filled pods that are beginning to lose their greenness	Beans and peas
Desirable size reached but still tender (over mature if colour dulls or changes and seeds are tough)	Eggplant or cucumber

Exudes milky sap when thumbnail penetrates kernel	Sweet corn
Seeds slipping when fruit is cut, or green colour turning pink	Tomato
Deep green colour turning dull or red	Sweet pepper
Easily separated from vine with a slight twist leaving clean cavity	Muskmelon
Change in fruit colour from a slight greenish white to cream; aroma noticeable	Honeydew melon
Colour of lower part turning creamy yellow, dull hollow sound when thumped	Watermelon
Curd compact (over mature if flower cluster elongates and become loose)	Cauliflower
Bud cluster compact (over mature if loose)	Broccoli
Big enough before flowering	Lettuce
Head compact (over mature if the head cracks)	Cabbage
Big enough before it becomes pithy	Celery

Mobile refractometers provide direct measurements of *maturity* in the field and can be carried out without harvesting the product. Hand-held refractometers are durable and very reliable (when used properly) field instruments for measuring sugars or soluble solids in fruits such as melons, citrus, pineapple and others. Some refractometers measure per cent sugars directly, while others measure soluble solids in Brix units that can be converted to show the percentage of sugar in the fruit. The 'Atago' type refractometer is self-compensating for temperature differences but other units need to refer to temperature compensation tables. More precise analysis can be provided by laboratory equipment such as photometers that measure the colour of products and spectrometers, which analyse the concentration of certain chemical components in plant tissues.

### 3.1.2 Picking Procedures

Once a fruit is plucked from a plant, or a root or leaf vegetable is harvested it is cut off from its source of food and particularly water. In general the quality of fruit and vegetables cannot be improved after harvest. Harvesting practices therefore aim to

cause as little mechanical damage to produce as possible. Gentle digging, picking and handling will help reduce crop losses. Picking of fruit and vegetables can be carried out mechanically or by hand. Mechanisation has a distinct advantage for larger growers in terms of speed and efficiency, but in most circumstances, harvesting by hand, if completed properly, will result in less damage to produce than machine harvesting and result in a superior quality. Machine harvesting is usually viable only when an entire crop is harvested at one time and is more useful for crops for industrial (processed or canned) than for the fresh market.

The effects of poor treatment normally show themselves some days later, when the produce is presented for sale or is in storage. Poor treatment has two effects: firstly the price is reduced and secondly, in the long term, the reputation of the production area is diminished (again tending to result in lower prices).

Hand harvesting is also usual where fruit or other produce is at various stages of maturity within the total crop and there is a need for repeated visits to harvest the crop over a period of time. A small cart with a single wheel in front can help reduce the amount of bending and lifting the picker has to do during harvest. This can be pushed along ahead of the picker.

For some crops e.g. strawberries, fine beans or peas, a natural break point forms at the junction of the stem and the stalk when produce is mature. Harvesting should be carried out by plucking the stem or pickers should grasp the product firmly but gently and pull upward. Wearing cotton gloves, trimming fingernails, and removing jewellery such as rings and bracelets can help reduce mechanical damage during harvest. When harvesting by hand, many tools can be used and the correct selection depends mainly on the crop. Occasionally diseases can be transmitted from plant to plant. Tools should be cleaned often and, when virus diseases are a problem, knives should only be used for trimming, not cutting the fruit from the plant.

*Tuber and root crops* are normally harvested with forks or hoes. The digging should start some 15 cms away from the base of the plant. In general, it is preferable to lever and pull the roots rather than attempt to dig the roots out. Harvesting is easiest when the soil is relatively dry as both damage and the need for washing is reduced.

Most staple roots and tubers that grow beneath the soil are likely to suffer mechanical injury at harvest because of digging tools even if harvested by hand. Harvesting of these crops is easier if they are grown on raised beds or mounds, or "earthed up" as is common in potato growing. This enables the digging tool to be pushed into the soil under the roots or tubers, which then can be levered upwards, loosening the soil and decreasing the possibility of damage to the crop.

Other root crops, such as carrots, turnips or radishes can be loosened from the soil in a similar manner by inserting the tool into the soil at an angle and levering the roots upwards. This method can also be used for celery if it has been earthed up or buried to blanch the stems.

*Vegetables.* Hands only, sharp knives or clippers can harvest either the whole vegetable or a part of the vegetative growth. Harvesting methods vary according to the vegetable to be harvested:

- The stem is snapped off by hand with leafy vegetables (e.g. spinach and lateral buds (e.g. brussel sprouts))

- ❑ With vegetables where the plants grow above ground (e.g. cabbage, lettuce, sweet pepper, egg plant and honeydew melons) the main stem can be cut through with a heavy knife and trimming is carried out in the field (the cut stem must not be placed on the soil). Knives must be kept sharp and clean at all times or they may spread virus diseases from plant to plant. Tools like this are used for harvesting lettuce, cabbage,
- ❑ Bulb vegetables (e.g. onions, leeks and garlic) can usually be pulled from the soil by hand or loosened by using a digging fork and then cutting the leaves about 3 cms from the bulb.
- ❑ Root crops (e.g. carrots) can be lifted by hand or simple tractor implements used to undermine bulbs and bring them to the surface

Flowering vegetables (e.g. cauliflower and broccoli) can be cut with a sharp knife and trimmed in the field or snapped off by hand (broccoli) and subsequently trimmed. Mature flowers (e.g. squash or pumpkin) can be plucked individually by hand.

*Fruit* can be picked carefully by hand, clipped or cut from the tree. Clippers or knives should be kept well sharpened. Protruding parts, woody stems or spurs should be trimmed as close as possible to prevent fruit from damaging neighbouring fruits during transport.

Many ripe fruits and some immature seed-bearing structures such as legume pods have a natural breakpoint at the fruit stalk, which can easily be broken at harvest. Fruit and other seed-bearing structures harvested at an immature or unripe green state are more difficult to pick without causing damage to either the produce or the plant. These are best harvested by cutting them from the plant, using clippers, secateurs or sharp knives. The clippers may be mounted on long poles for tree fruits and with a bag attached to the pole to catch the fruit.

Pruning shears are often used for harvesting fruits, some vegetables, and cut flowers. A variety of styles are available as hand held or pole models, including shears that cut and hold onto the stem of the cut product. This feature allows the picker to harvest without a catching bag and without dropping fruits.

Fruit trees are sometimes quite tall and letting fruit fall to the ground when it is cut from the tree will cause severe bruising. If two pickers work together, one can clip or cut the fruit from the tree, and the other can use a sack to break its fall. The catcher supports the bag with his hands and one foot, catches the falling fruit and then lowers the far end of the bag to allow the fruit to roll safely to the ground.

### **3.1.3 Field trimming, cleaning, grading and packing**

Removal of wounded leaves, stems or roots is often made before packing and wrapping of many vegetables, or a large amount of the leaf is taken off and in some cases completely eliminated. Cabbages, cauliflower, chinese cabbage and lettuce will have their outer leaves trimmed, except for three or four paper leaves, to give some protection to the head. Long stalks attached to the fruit can be cut as close to the fruit as possible to prevent damage to other fruit. In these cases the presentation of the product is improved. Improved water retention also results as minor transpiration and contamination are reduced.

It is important to pack produce in bags following these operations in order to protect it from any shocks. Garlic can be packed in plaits or as single bulbs with prior complete elimination of the leaves, but sprouting and decay are still likely to develop. For root vegetables, washing performs the indispensable task of eliminating dirt so the crop looks better for the market. However, this operation can result in high weight losses and may increase development of mold if the interval between treatment and consumption is too long (e.g., carrots, potatoes, celery, turnips and radishes).

It is highly recommended to wash leafy vegetables in order to eliminate dirt, but it is also necessary that the product does not hold too much water so increases microorganisms (i.e. lettuce, cabbage and spinach). Microbial growth depends on either the diffusion of the microorganisms or damage caused by handling. It has been shown that the use of chlorine in water (100ppm) considerably reduces decay. Brushing also cleans fruits or tubers and makes them more shiny. However it can also cause bruising and accelerate ripeness.

When crops are field packed the picker harvests and then immediately packs the produce after minimal handling. The packing of produce directly into marketing packages in the field at harvest will reduce the damage caused by multiple handling and is used increasingly by growers.

Strawberries are generally field packed, as even a small amount of handling will damage these soft fruits. When lettuce is field packed, several wrapper leaves are left on the head to help cushion the produce during transport.

A simple aid for field packers is a movable cart with a rack for boxes and a roof to provide shade. This cart is designed so it can be pushed along the edge of the field being harvested. The roof should be able to fold down for easy transport, and open up to provide a wide area of shade for the pickers/packers and produce. The cart design can be modified as needed to suit various products and different operations. It could be designed for pulling by a small tractor into and out of the field, and used for field packing many types of crops.

Produce for long-term storage should be disease and blemish free and therefore needs to be sorted. When transport is expensive it is often only justifiable to send top quality crops. Produce is generally separated according to quality criteria, it may also be graded according to ripeness or colour or size. The crop is then normally packed into different containers. This facilitates marketing into different markets.

Grading and packing is often carried out on the ground, under the shade of a tree. This is both unhygienic and inefficient. Specialist grading areas or sheds are better and are generally open sided, with tin or preferably roofs from natural materials. Grading while standing or sitting at tables enables people to work faster. Tables covered with polythene sheeting are easy to clean and the sheeting can be replaced cheaply. Lighting should be good. Tin roofs can be painted white to reflect heat while water trickled down the outside of a shed helps to reduce the heat inside the building.

### **3.1.4 Harvest containers**

Harvest containers must be handy for the picker to use while moving through the field and ensure minimal mechanical damage for the product. Baskets or boxes with sharp or rough edges should either be avoided or lined with paper or leaves. Damage is often caused by transferring produce from one container to another. If possible, produce

should be harvested into the container in which it will be stored or transported. A number of different types are available including:

- ❑ *Harvesting bags* with shoulder or waist slings that can be used for fruits with firm skins like citrus and avocados. They are easy to carry and leave both hands free. They should be designed for opening at the base to allow produce to be emptied through the bottom into a field container without tipping the bag
- ❑ *Plastic buckets* or other containers suitable for harvesting fruits that are more easily crushed, such as tomatoes. The containers should be smooth, with no sharp edges or projections to damage the produce
- ❑ *Baskets* as long as they do not have sharp edges or splinters that can injure produce. If they are not sturdy, they may bend out of shape when lifted or tipped- especially if they are large and crush or otherwise damage the contents
- ❑ *Bulk bins*, usually of 250 to 500 kg capacity and mostly used by large growers, where crops such as apples or cabbages are sent to houses for selection, grading and packing or for canning/freezing or processing. Bins can be carried by a forklift attachment on a tractor that moves produce from harvesting points to assembly areas

When unventilated bulk bins are used in the field, produce should only be left in them briefly and protected from sun or rain. Produce held in bulk for long will overheat and be more subject to decay. Bulk bins transported over long distances must be perforated to minimize heat build-up in the contents.

Picking baskets, bags and buckets come in many shapes and sizes. Harvesting containers can be made by sewing bags with openings on both ends, fitting fabric over the open bottom of ready-made baskets, fitting bags with adjustable harnesses or by simply adding some carrying straps to a small basket.

Plastic crates are relatively expensive but are durable, reusable and easy to clean. When empty, they can be nested to save space in storage or transport. When filled they can be stacked if every other crate is turned in the direction opposite to the one below.

### **3.1.5 Mechanisation and produce damage**

Harvest mechanisation is particularly useful in certain circumstances and in particular for:

- ❑ Harvesting potatoes, onions, celery and some other root crops and where simple tractor-drawn harvesters lift up the crops and leave them on the soil surface for later hand picking and grading
- ❑ In transporting produce from the harvesting point to the assembly area to await further transport. Normally involving tractors and trailers with laden containers, pallets or bins.

Machine harvesting equipment is usually only economically feasible only for producers with larger fields, with crops that are harvest only once (e.g. legumes) and where labour is difficult to obtain or relatively expensive. Mechanically harvested produce is subjected to more damage during harvest (although some root crops can be severely damaged by careless hand digging) and results in inferior product quality that is normally only acceptable for canning or processed markets.

Careless handling of fresh produce causes internal bruising and this results in abnormal physiological damage, splitting and skin breaks and thus rapidly increasing water loss and the rate of normal physiological breakdown. Skin breaks also provide sites for infection by fungi's that cause decay. The more careful the handling the slower is the deterioration in quality.

Damage during harvest can become a serious problem, as injuries make produce decay faster, increase water loss and respiratory and ethylene production rates and so leading to rapid deterioration. Containers used by pickers in the field should be clean, have smooth inside surfaces and be free of rough edges. Stackable plastic crates, while initially expensive, are durable, reusable and easily cleaned. If baskets are used, they have to be woven "inside out" with sharp edges on the outside of the basket.

Pickers have to be well trained in harvest techniques in order to minimise damage and waste, and should be able to recognise the proper maturity stage for the produce they are picking. Pickers should be also trained to empty their picking bags and/or baskets with care and never to dump or throw produce into field containers. Snapping, cutting or pulling the fruit or vegetable from the plant needs to be carried in the least damaging manner. Vented, stackable field containers should be periodically cleaned and smoothed and the tips of knives should be rounded to minimise inadvertent cuts and excess damage to plants. Knives and clippers should always be well sharpened. Containers must be emptied carefully to minimise drop heights and fruit to fruit damage. If picking is directly into large bulk bins, produce can be protected from bruising by the use of a de-accelerating chute made from canvas or similar material.

Exposure of produce to the sun should be avoided as much as possible both during and after harvest, as produce left out in the sun will gain heat and may become sun-burned. If delays are expected in removing them from the field, field bins should be placed in the shade or loosely covered (for example with a light coloured canvas, or by leafy plant materials, straw or an inverted empty container). Night or early morning harvests are an option for harvesting produce particularly when internal fruit temperatures are relatively low. This reduces the energy needed for subsequent cooling. Latex flow is often lower later in the morning than it is at dawn for crops such as mango and citrus and will reduce the later efforts that will be required for cleaning produce before packing.

Any practice that reduces the number of times produce is handled will help to reduce losses. Field packing (selection, sorting, trimming and packaging of produce at the time of harvest) can greatly reduce the number of handling steps the produce must undergo before marketing. Small, mobile field packing stations can be designed to be moved along with the packers and so provide shade for packing operations.

Potato damage is a good example of losses during pre-harvest and post-harvest operations. The main types of damage are as follows:

1. External damage which can be readily seen with the help of chemical staining, classified and then quantified using a simple damage index
2. Bruising which can be examined by either slicing or peeling tubers to expose the bruises after a storage period in a warm atmosphere, or more quickly by using a "hot box".

A large part of mechanised harvester damage is caused by the lifter and the elevator. Damage also occurs as potatoes transfer between the two particularly when a smooth flow from the ground is interrupted by blockage, so that the crop is almost stationary when it meets the moving machinery.

The most important single component of diggers and harvesters, capable of inflicting severe damage are moving parts and the speed of which influence the extent. The ratio between the elevator and ground speed is an important control factor and this ratio has to be kept as low as possible by reducing elevator speed whilst maintaining a suitable forward speed.

### **3.1.6 Field heat and cooling techniques and equipment**

Directly following harvest and, when produce is prepared for marketing, cooling of fresh produce is essential. Cooling (also known as "pre-cooling") is the removal of field heat directly after harvest and before any further handling. Any delays in cooling will shorten post-harvest life of produce and reduce quality. Even produce undergoing repeated cooling and warming deteriorates at a slower rate than produce that has not been cooled.

Immediate cooling will minimise the respiratory rate that is very intense in some products. All leafy vegetables and the products that are harvested as immature fruits (e.g. green beans) respire more intensively than bulbs, roots and mature fruits. For extending their post-harvest life it is essential to reduce field heat before transporting them to a packhouse.

With perishable produce damp cloths can be used to give protection against the sun's heat. Field containers should be removed to a shaded area as soon as possible. Some leafy vegetables may be sprinkled with water at intervals to maintain water content. Field assembly points, such as a shade house made out of natural materials or a canvas tent, should be used in order to keep the produce cool and allow ventilation.

If a small amount of leafy vegetables are being harvested a small tub of cold water can be useful for cooling the produce. The tub can be brought directly to the field and used by the picker as a field container. Clean water should be used with each lot of produce. Chilling leafy vegetables by using cold water at harvest will help maintain quality and prevent wilting. Highly perishable products such as specialty lettuces will require special handling. They will need to be immersed in near-freezing water almost immediately after harvest. Rapid removal of field heat is essential to maintaining product quality, and is a key element of professional handling.

### **3.1.7 Field curing**

The self-healing of wounds, cut and bruises is known as curing. The term is applied to the measures used to prepare starchy staple root crops and onions for long-term storage. Curing root and tuber crops is an important practice if these crops are to be stored for any length of time. Curing is accomplished by holding the produce at high temperature and high relative humidity for several days. Wounds heal and a new, protective layer of cells are formed. While curing can be costly initially, the long extension of storage life often makes this practice economically worthwhile. The best conditions for curing varies amongst different crops. The method of curing root crops is quite different from that used on onions, garlic or flowering bulbs.

*Root crop curing.* Potatoes and several other roots and vegetables have the ability to heal skin wound when held at moderately warm conditions and high humidity for several days after harvest. Although details vary from crop to crop the following conditions must always be observed:

- ❑ The roots and tubers must be kept at an appropriate temperature, normally somewhat higher than ambient, in order to stimulate new skin growth
- ❑ The atmosphere must be kept moist but without free water on the surface of the roots or tubers, no new skin will be formed in dry air on injured surfaces
- ❑ Some ventilation is needed for new skin growth, but an excessive air flow will dry the atmosphere and cause a drop in temperature
- ❑ Temperature must be kept steady, if it falls, water will condense on the surface of the roots and tubers and will encourage bacterial soft rot

Because all root and tuber crops are damaged to some extent during harvest and handling, curing must be carried out as soon as possible. This can be done by limiting ventilation, thus allowing the temperature to raise enough to promote curing. At the same time the air will become moist owing to the normal production of water by the roots and high rate of evaporation from injuries.

*Curing dry bulbs,* The storage life of onions, garlic and flowering bulbs is extended by exposure to warm dry conditions for several days to dry the outside skin and prevent the ingress of spoilage organisms. Carried out immediately after harvest it is a drying-out process. The dried layers of skin protect the produce from further water loss during storage. This process is also known as curing although physiologically it is rather different and causes about 5% weight loss. The dried layers of skin protect the produce from further water loss during storage.

The bulb crops are undercut in the field, when weather conditions are suitable, windrowed and then left to dry for five to ten days although curing may take up to ten days, depending on weather conditions. Alternately the product is subjected to forced circulation of warm dry air when first put into storage. If forced heated air is used for curing onions and other bulbs, one day or less at 35 to 45 C (95 to 113 F) and 60 to 75% relative humidity is recommended.

Under dry, warm conditions harvested onions are left in the field for a few days until the green tops, outer skins and roots are fully dried. Under wet conditions, it may be necessary to dry onions on racks or trays under cover. The dried tops of the plants can be arranged to cover and shade the bulbs during the curing process. This protects the produce from excess heat and sunburn. Produce should be checked daily to see when the outer skin and neck tissues are properly dried. Onions and garlic can also be cured after packing into large fibre or net sacks.

The curing of onions is necessary because:

- ❑ The necks of onions are very sensitive to decay if they remain wet, especially if the green tops are cut off before harvest
- ❑ Drying the outer skins of the bulbs reduces decay and water loss;

- ❑ Roots damaged during harvesting are a common entry point for decay unless they are dried quickly

Cutting off the green tops of bulb onions is not recommended for small-scale producers because it greatly increases the risk of losses from decay if the bulbs cannot be dried quickly under controlled conditions. In large-scale commercial production, where the green tops are cut off mechanically before harvest, drying is often carried out using artificial heat with forced ventilation. This technique is not economical for small-scale production. Field dried onions can be stored up to two months under ambient conditions in well-ventilated trays on pallets or in a field windbreak. Dried onions should never be allowed to come into contact with damp soil.