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INTRODUCTION

Bananas and plantains are grown under a wide range of environment in Kerala, producing crops year round thereby providing a steady source of income. Of the thirty odd banana varieties under cultivation in the state, the French plantain cultivar Nendran (*Musa* AAB) is predominant and grown commercially. It is valued as a dual purpose variety, and extensively used in the preparation of chips and other value added products. Due to the very high demand, this variety has a steady market as reflected in the relatively higher prices realized and thereby plays a pivotal role in the livelihood security of farmers. Tamil Nadu also produces a sizeable quantity of Nendran targeting the domestic demand in Kerala.

Nendran is also in great demand in the Gulf countries by virtue of the large Indian population. The growing demand is partially met by export of fruits by air, but the process is limited by the expenses involved. The setting up of Agri Export Zones by the Ministry of Commerce and Industry, Government of India, has further brightened the export prospects of this variety

Banana is highly perishable in nature. Handling at ambient temperature, poor marketing and storage facilities lead to tremendous quantitative and qualitative losses Therefore improved pre harvest and post harvest handling practices are important. Under pre-harvest practices, timely cultivation, adequate use of chemical fertilizers, avoidance of moisture stress, plant protection and bunch management practices are important. Export of fruits demands high standard of quality regulated at grading and packing levels.Export plantations have developed methods of handling bananas to minimize this wastage by establishing cable ways for moving bunches to packing sheds where fruit is dehanded washed, treated with fungicide to reduce post harvest losses and placed into cardboard cartons for transport.

One of the keys to minimizing losses from post harvest losses is to make use of the natural resistance of green banana fruit by preventing the initiation of ripening. Another is to control the post harvest environment both before and after ripening begins Losses are reduced by improved management of ripening through better temperature control and reduced transit times. In the case of Cavendish varieties, which rule the international market, pre and post harvest handling techniques oriented towards export are streamlined. In these varieties effective temperature control is used to prevent fruit ripening during transit. Many ships transporting bananas also have controlled atmosphere conditions to reduce the incidence of ripening. In the absence of a specific protocol for the sea shipment of Nendran, it would be necessary to adopt the procedures developed for Cavendish cultivars. Further refinement can be brought about based on variety specific information gathered through experimentation.

BACKGROUND INFORMATION

Genetic variability

Nendran belongs to the French Plantain subgroup, a unique type of bananas where the fruit remains starchy at ripeness. The long, slender, angular and pointed fruits and orange color of the fruit pulp at ripeness set it apart from other varieties. Nendran in

Kerala is represented by a number of clones recognizable through variation in plant stature, pseudostem color, bunch morphology and degree of development of the male phase. Under a World Bank funded Banana improvement programme implemented at the Banana Research Station, Kannara, the variability in Nendran was collected characterized and classified into ten morphotaxonomic groups. Chengalikodan, Nedu Nendran, Manjeri Nendran, Kottayam Nendran, Kaliethan and Myndoli (Quintal Nendran) are some of the popular clones cultivated extensively in Kerala.

Agrotechniques

In Kerala, majority of the growers are small/marginal farmers cultivating the crop for home consumption or local markets. Cropping system varies with region, ranging from subsistence intercropping to intensive monocropping. Research efforts at the Kerala Agricultural University have resulted in the development of package of practices and recommendations for the cultivation of Nendran and other banana varieties. Well drained soil that is not too acid and rich in organic matter is preferable. Bananas in general require high nitrogen, adequate phosphorus and plenty of potash which are only partly supplied by the soil. Therefore large quantities of mineral nutrients have to be added to maintain soil fertility and to sustain continuous high yield.

Bananas also require large amount of water for sustained yields and therefore production should be supplemented by an efficient irrigation system. Based on conducted at the Banana Research Station, Kannara, irrigating at 20 CPE is found optimum for Nendran which would mean a total of 2,000 l of water per plant during a crop cycle of 9-10 months.

The cultivation of Nendran in Kerala is constrained by its susceptibility to several fungal, bacterial and viral diseases, insect pests and nematodes. Timely management practices are essential to bring about effective control. Operations such as weed control, desuckering and propping influence productivity and quality. Continuous cultivation for more than two years depresses the yield and therefore crop rotation has to be practiced. Rotation of Nendran with cassava besides being highly remunerative serves as a potential rotation against burrowing nematodes, *Radopholus similis,* a major limiting factor.

Bunch Management

Debudding and dehanding

At the time of bagging the male bud is snapped off because in some circumstances this practice can increase bunch weight. The male bud is removed when the peduncle is at least 15 cm below the last female hand. Along with the male bud, the false hand which is an incomplete hand having mixed male and female flowers is also removed. Dehanding reduces the amount of cull fruits and handling at the packing station. In dehanded bunches maturity is hastened by 2-3 days.

Bunch covering

Export bananas need to be as blemish free as possible at markets to obtain premium prices. Bagging is essential to prevent losses from insect and bat damage and leaf scarring. The bunch is therefore usually covered with a perforated polythene sleeve, cover or bag soon after emergence of all the hands to protect from rubbing leaves, wind blown debris and chemicals used in sprays to control leaf spot diseases. The bag should be sufficiently long to extend 15-30cm above the top hand and 25 cm below the apical hand. It is tied around the peduncle well above the first exposed hand.

Prior to placing the bag the large bract leaves are pushed away from the fruit. In windy areas, the bag is tied at the bottom to prevent the polythene rubbing on the fingers, which causes scarring. If the bottom of the bag is tied, the knot is positioned at one side to allow rain water to drain freely from the bag. This is because a build up of humidity within the bag can lead to fungal disease problems on the fruit.

After installing the bag, a colored ribbon is tied to the peduncle to indicate the week bagged for controlling the age at which fruit will be harvested. Bagging can also shorter the fruit maturation period by 3-4 days and increase the weight of the bunch marginally.

Maturity indices for scheduling harvest

Fruit maturation is an important post harvest criterion because the stage of maturation at which fruit is harvested greatly influences the green life or the ability of the fruit to be stored for long periods and its final eating quality. Fruit harvested during an optimum period will develop its characteristic flavor, taste and color during storage. Fruits harvested at an early stage of maturity are susceptible to shriveling and mechanical damage and are of poor quality on ripening. The maturity index must consistently ensure minimum acceptable eating quality and a long storage life. By knowing the stage of maturation, it would be possible to schedule harvesting, handling and marketing operations efficiently.

Unlike locally consumed fruit left on the plant until ripe, bananas for export or fruits destined for distant markets are usually harvested at a stage known as 'three quarters full' when the fingers are clearly angular green and immature.

Age control

Proper age control or assessment of bunch age of banana is important in deciding the time of harvest. This can be determined by tagging bunches on emergence and then calculating the approximate harvest dates. Calculating the number of days from bunch emergence to harvest provides one of the best and reliable indicators of estimating bunch age. Usually coloured ribbons are tied around the peduncle, the colour of the ribbon signifying the particular week of emergence. When the bunch reaches the harvesting age, maturity or grade of the fruit is checked by measuring the diameter of the middle finger on certain hands with a caliper. The bunch is harvested at the desired grade.

Inadequate age control at harvest is one of the factors predisposing banana consignments to show a proportion of 'ship ripe' fruits at their eventual destination. Lack of age control may also result in the harvesting of under filled or immature fruits.

the relationship between bunch age and green life was evaluated and the conclusion is that age management reduced the problem of premature ripening but was not sufficient to eliminate it.

Fruit size : Diameter

A procedure widely used in commercial companies to tell whether a bunch is ready for harvest is to measure the caliper grade of the fruit. The appropriate caliper grade needs to be determined for each cultivar, market and location. This procedure means that fruit is harvested at an immature stage and usually reduces the problem of fruit ripening in transit.

Fullness

A common and long used criterion is that of 'fullness'. This is a visual estimation of the angularity of the fruit. For long distant markets, fruits are harvested "three quarters full", when the fingers are still clearly angular and green. For local markets 'full' or rounded fruit is acceptable.

Storage

Bananas and plantains at commercial maturity have a relatively short post harvest life. The term storage involves management of the fruit to achieve a suitable quality after a planned period of time and consists of the use of environmental factors to extend green life, to manage the rate of ripening or to extend shelf life.

If the growing area is close to the market, then the fruit may need to be stored for only a few hours or a day. On its journey from the plantation to the consumer, the fruit goes through the preclimacteric, climacteric and post climacteric stages of development and experiences a range of humidity, temperature and gaseous environment. The journey includes changing biological (fruit pathogens) and kinetic energy (Mechanical damage) environments that interact with the changing physiology of the fruit.

Managing green life and shelf-life

Storage is about managing green life, the initiation of ripening and subsequent shelf-life usually with the aim of prolonging green life and shelf life. Green life is defined as the well defined period after harvest during which the fruit remains green and firm .It is also referred to as pre climacteric phase. Once the green life of the fruit has ended and ripening has initiated, it is irreversible.

Shelf-life is the time over which the ripe fruit remains acceptable for consumption. It is the period between initiation of ripening (*i.e.*, end of green life) and end of saleable life. The three most important factors governing green life are the maturity of the fruit at harvest, the environmental conditions experienced by the fruit after harvest and the gaseous composition of the atmosphere around the fruit, especially ethylene concentrations.

Storage temperature

The lowest temperature at which green bananas can safely be held to delay ripening is about 13°C pulp temperature below which they become chilled and injury

to the peel results. Green bananas are shipped at a temperature range of 13-14°C pulp temperature. Ethylene levels within polythene bags packed with bananas with transit cooling were lower than in polythene bags without transit cooling during storage.

The relationship between the natural log of green life and temperature over the range of 15-35°C is linear with a slope of 0.0.045 days $day^{-1}°C^{-1}$ for the Cavendish cv. Mons Mari. The relationship between respiration rate and green tip is exponential, with the natural log of green life being proportionate to respiration. This means that to reduce green life by reducing respiration rate, large reductions in respiration will be necessary to achieve a significant extension of green life.

Shelf life (defined as the time for the colour stage of the fruit to change from 4 to 6) is affected not only by temperature during the shelf life period, but also by the temperature during the prior period of ripening. Eg. Shelf life of cv. 'Williams' fruit ripened at 16°C was ten days if, after five days of ripening, the fruit was removed to 21°C. Ripening the fruit at 19°C and adopting the same removal time and temperature, however reduced shelf life to two days.

Modified and Controlled Atmosphere Storage

The modified atmosphere technique in combination with refrigeration is being used in international trade. The purpose of modifying the atmosphere around green bananas during pre climacteric phase is to extend the green life and hence prevent premature initiation of ripening during transit and storage. Ripening is delayed by reducing the O_2 level to 3-7 percent, increasing CO_2 to 10-13 percent and absorbing ethylene. Usually the atmosphere in the holds of the ships containing banana cartons is modified using sophisticated technique. However the benefits of modified atmosphere storage can be achieved in other ways. Fruits can be packed in polythene bags and vacuum applied in each bag before it is sealed and the carton closed. The atmosphere within the bag is modified by the respiratory activities of the fruit. If transported under refrigeration, the system combines the beneficial effects of reduced temperature and modified atmosphere.

Traditionally to prolong green life fruit needs to be harvested at a suitable maturity, stored at low temperature to reduce the respiration rate and stored in an ethylene-free environment. Sealing fruits of cv. Williams in polyethylene bags at ambient temperatures modified the atmosphere and extended green life by six days. Incorporating potassium permanganate as an ethylene absorbent into the package extended green life by another 14 days. Thus modified atmosphere, together with an ethylene absorbent, added 20 days to fruit green life and substituted to same extent temperature control. Studies with different cultivars revealed differences in the length of time. They will remain green in modified atmosphere, 13-25 days being recorded at room temperature. Cooling to 15°C usually doubles this storage life.

In studies to explore the interaction between temperature, polyethylene bags and ethylene absorbent using cv. Williams (AAA), it was observed that as temperature rises, green life is found to decrease exponentially. Polyethylene bags that include an ethylene absorbent increase storage time across the whole range of temperatures. Without an absorbent, ethylene accumulates in the bag and reaches physiologically active concentrations, which has the effect of reducing green life by about 14-18 days irrespective of temperature of storage. It was also observed that

ethylene negated the effects of low oxygen and high carbon dioxide concentrations in delaying the climacteric. They also found that low O_2 and CO_2 inhibited ethylene synthesis and concluded that this may be a major effect of controlled atmospheres in prolonging storage life. Studies in Africa, where plantains are major varieties, showed that modified atmosphere could delay ripening in plantains under tropical ambient condition by using sealed polythene bags containing sawdust impregnated with saturated potassium permanganate

Thus the post harvest life of fruit can be extended by reducing the rate of respiration through low O_2 and high CO_2 concentration. The ultimate green life achieved is likely to be determined by what happens to the ethylene that is generated by the fruit.

Banavac bags

Ripening can be delayed by using a controlled atmosphere in polyethylene bags of specified thickness. Banavac bags are 0.4mm thick, which increases the CO_2 to above 5 per cent and decreases the oxygen to 2 percent. The insertion of potassium permanganate, an ethylene absorbent in the bag is very effective for delaying ripening.

Chilling injury

Both green and ripe bananas are susceptible to chilling injury, but green fruits are more susceptible. Chilling injury injures the peel, killing certain cells which darken and gives the peel a characteristic smokey or dull yellow appearance after ripening rather than a bright yellow colour. Ripe fruit if chilled turn dull brown when later exposed to higher temperatures and are very susceptible to handling marks, the slightest pressure causing discoloration. Generally temperatures below 12°C cause chilling injury.

Symptoms of chilling injury

Symptoms of chilling injury are not readily apparent at the injurious chilling temperatures, however they become increasingly apparent after transfer of fruits to non chilling temperatures. These include

- Surface lesions such as pitting, large sunken areas and discoloration of the surface
- Dark water soaked areas of the peel
- Internal discoloration of pulp
- Breakdown of tissues
- Failure of fruits to ripen normally following removal to ripening conditions.

In severe chilling the green fruit develops extensive sub epidermal browning or blackening and the peel may become entirely black during ripening. When chilling is less severe, green fruit show no visible effect but on ripening the color of the peel varies from a dull yellow to grayish yellow or grey. These symptoms arise from accumulation of oxidized phenolic substances in the epidermal, or sub epidermal areas, accompanied by some retention of chlorophyll. In ripe fruits general appearance of fruit is one of dullness, the peel having an almost grayish cast, the pulp

remaining unaffected. Severely chilled fruits develop extensive sub-epidermal browning and eventually turn black. There is a loss of development of the characteristic flavor aroma and taste and often the development of off flavor.

Assessment of chilling injury

Chilling injury may be assessed as follows

- Subject both unripe and ripe fruits to varying durations and varying temperatures at or below 12°C
- Tranfer fruits to non chilling temperatures (eg ambient temperatures 20-25°C) for 24 - 48 hrs for observation and record symptoms development
- The symptoms listed above may serve as a guide

Ripening

Banana fruit produces ethylene, which triggers ripening. Ripening involves the conversion of starch to sugar, a softening of the fruit texture and often a change in skin colour from green to yellow.

Bananas harvested green passes through three physiological stages. The pre climacteric or pre ripening phase during which the fruit's metabolic activity is relatively low

- Ripening which begins with an intense burst of respiration, called the climacteric
- Senescence, during which metabolism slows once more

The ripening process has been divided in to seven stages as indicated by color changes. These are 1-green, 2-green with a trace of yellow, 3-more green than yellow, 4-more yellow than green, 5-only a green tip remaining, 6-all yellow, 7-yellow flecked with brown.

Changes in chemical composition during ripening

Water

The most abundant constituent of banana fruit is water. The peel of green bananas has 90 percent water and that of unripe plantains slightly less than 86 percent. There are larger differences between bananas and plantains in the water content of the pulp, which is about 75 percent in bananas and 60 percent in plantains. Ripening increases the water concentration in the pulp of Giant Cavendish bananas from 73 to 82 percent.

Carbohydrates

During ripening starch hydrolyzed to sugars. Features among cultivars are the concentration of starch in the ripe fruit, the amount of starch remaining when the fruits are fully ripe and the relative abundance of reducing sugars; compared with total sugar. For example, in unripe fruits there may be 15 percent starch (fresh weight) in the pulp of Cavendish cultivars (AAA) to 35 percent in the pulp of a Nigerian plantain. After ripening the starch content may be up to 15 percent in plantain. Total

sugars vary from 7 percent to 25 percent in Puerto Rican plantains. Reducing sugars in unripe fruit vary from one fifth of the total sugars in Red group banana, (AAA) to 100 percent in plantain (AAB).

Studies on starch and sugar changes in the fruits of two plantain cultivars at ambient condition at three stages of ripeness showed a decrease in pulp firmness and starch content of the pulp and a significant increase in the reducing content and brix of pulp.

Acids

Malic, citric and oxalic acids are the main acids of ripening bananas. Ripening doubles, in same cases trebles fruit acidity in certain cultivars with A and B genome. Despite the increase in acid with ripening the increase in sugar is greater and the sugar : acid ratio, which is an important component of flavour, increases from 40 in unripe fruit to 100-180 in ripe fruits depending on the cultivar.

Phenolics

Dopamine is the main substrate for browning in banana. Its concentration in the pulp of unripe fruit is about 50 mg (of pulp fresh weight^{-1}), but is halved as the fruit ripens. The concentration in the peel of green fruit is about 700 mg (peel fresh weight^{-1}) and ripening reduces its concentration to less than one-third. The rate of browning in homogenized pulp is a function of the concentration of dopamine and ascorbic acid (which inhibits the browning process) rather than the concentration of polyphenol oxidase.

Tannins are water-soluble phenolics found in the peel and pulp of bananas. In partially ripened fruit they impart an astringent taste. Ripening polymerizes the tannins, resulting in a loss of astringency. Tannin concentration in the green fruit of Cavendish group increased as the fruit aged. Increased concentration during winter, than in summer has been related to the rate of ripening.

Nitrogen concentration and proteins

High amounts of N fertilizer can shorten post harvest green life. On a dry matter basis, N is lower in the pulp of plantains than bananas, but on a fresh weight basis there is little difference. The same is true for N in the peel.

Volatiles

Volatile compounds are derived from leucine and valine, which increase in concentration as ripening progress. Fatty acids are also precursors. The main volatiles are acetate and buterase esters but alcohols, aldehydes, ketones and phenol esters are also produced. The banana flavour is due to amyl esters and the fruitiness is attributed to butyl esters. Volatiles are produced late in the respiratory climacteric over a period of four days.

Flavour

Sensory evaluation is an important aspect of fruit quality. Colour quality, eating quality and firmness were examined in Cavendish fruit ripened at 13-33°C. Firmness of pulp decreased continuously from 16-30°C. Colour quality was high and

unchanged from 13-24°C but it became unacceptable above 26°C. Eating quality on the other hand was high from 13-27°C while it decreased slightly at temperature above 27°C, it was still very acceptable. Thus fruit ripened at a high temperature would be rejected on the basis, of colour even though it was acceptable to eat.

Ripening conditions

Banana ripening is accomplished at temperatures ranging from 14°C to 20°C pulp temperatures with high relative humidity of 90-95 percent. Ripening temperatures between 14°C and 18°C are usually best when ethylene is used. Within certain limits, the ripening period can be extended or shortened to meet trade requirements by adjusting the temperature as shown below-

Approximate daily pulp temperatures desired for bananas scheduled to complete ripening in specified number of days.

Ripening schedule	Fruit temperature (°C)						
	1	2	3	4	5	6	7
4days	18	18	17	16			
5days	17	17	17	17	16		
6days	17	17	16	16	16	14	
7days	16	16	16	16	16	14	14

Ripening characteristics of bananas vary with country of origin, cultivar, days in transit, season of the year, maturity when harvested and other factors. The desired high humidity required for proper ripening is attained when bananas are held in boxes with polythene liners. After coloring is well underway the relative humidity should be 85 percent. Low relative humidity hastened the yellowing of the peel and advanced the onset of respiratory climacteric and ethylene production by about 6 and 12 days at 65 percent and 95 percent RH respectively at 20°C. Fruits held in the higher RH combination after ethylene treatment had greener peels and firm fruits with less scarring and high relative humidity caused less compression injury.

Air circulating fans are operated continuously when ripening boxed fruit so that a uniform pulp temperature is maintained throughout the room. Stacking to allow adequate air circulation is essential for uniform ripening of boxed bananas. Ideally boxes should be stacked in rows with a10 cm air channel between adjacent rows

Role of ethylene

The addition of ethylene gas to ripening rooms always is recommended to stimulate ripening of tropically boxed bananas. Ripening at controlled temperature also ensures affirm pulp texture, good color and flavor A concentration of 1,000p/m or $1ft^3$ ethylene or $1ft^3$ ethylene /1,000ft^3 of room volume is commonly used. After 24 hours of ethylene treatment the rooms should be ventilated. Such a treatment assures

uniform coloration on a pre determined schedule and allows use of lower than normal ripening temperature, which will result in increased shelf life.

The best holding temperatures for ripe bananas is 13°C. Even at these temperatures ripe fruit cannot be held for more than 2-4 days. Ripening should be timed so that holding ripe fruit is kept to minimum.

Application of ethylene

Application of ethylene gas should be done when pulp temperatures are between 14 and 18°C at a rate of 1,000 ppm (1 litre ethylene per $1m^3$ room space). After application the room should be closed for 24 hours and then the rooms are opened daily for 20 minutes for room aeration. Once the fruit reaches the color stage 4 the pulp temperatures should be kept at 13-14°C.

Defective ripening

Exposing ripe bananas to temperatures higher than those in the ripening range hastens softening and decay, weakens the neck and cause poor color. The term 'cooked' is normally used to describe this type of injury in its extreme stage. Uneven ripening can be caused by low temperature and insufficient ethylene.

Storage and ripening rooms

Ripening rooms are used for both ripening and storage. In general a 100 box ripening room requires $14m^3$ of interior space. The walls, ceilings and doors should be well insulated and gas tight.

For storage purpose, fruits can be held at 13-15°C up to 28 days in regular packs and up to 40 days in controlled atmosphere packs (Banavac). The room must be free of ethylene or ripening fruit (which produces ethylene). Fruit in storage is ventilated by opening the doors daily for 20 minutes.

Packing stations and packaging

All bananas in international trade must pass through a packing station. There the hands are removed from the stalk and defective fingers are discarded. The exportable fruit is placed in moving water to remove latex flowing from fresh crown cut and then packed in cardboard carton.

Principal features of a packing station

- A shaded holding area where harvested bunches are hung
- A de handing area
- A de handed tank full of flowing water in which hands cut from the stalk are placed for dividing in to clusters of four to eight fingers and for removal of defective fingers and clusters.
- A de latexing tank full of clean flowing water to remove latex flowing from the crown surface of clusters.
- Trays or turn tables for placing clusters to be weighed
- A scale and assembled cardboard cartons and plastic wrappers for packing the fruit.

In addition a detached area for assembling and storing cartons usually adjoins the packing station. All of the work areas are connected by roller conveyors.

Packing, packaging materials and type of packs

The standard containers used are the carton holding 18 kg of fruit net weight and 12 kg carton used in Japan and Middle East. A typical UF42 box top is 15" wide x 20 ¾" long and 9 5/16" high. The assembled boxes consists of four pieces-the box top, the bottom a wall reinforcing liner and a tunnel pad or divider for separating the row of clusters. The arrangement of clusters in the box requires some skill to avoid bruising and scarring.

The basic procedure for packing an 18kg box using a polyethylene bag as liner is as follows.

- The bag liner is opened and placed in box and adjusted to fit the box
- Two rows of banana clusters are packed
- The protective tunnel pad is folded over
- Two additional rows are packed above the tunnel pad, clusters must be properly fitted.
- The bag surplus is gathered and twisted to close and then tucked between the fingers.
- The cover is placed on the box in such a way that ventilation holes match those in the bottom of the box.

Before leaving the packing plant, the box is stamped with a numbered code that indicates the following.

a. Identification number of the packing plant
b. Date fruit packed
c. Identification number of the producing area.

Packs are classified based on the plastic liner used in the box, the type of box or the class of fruit. Some of the different liners used are a plain plastic sheet (slip sheet), plastic bag perforated or non perforated (polypacks), small bags for each individual clusters with a printed brand name (cluster bag) or a modified atmosphere bag (Banavac). Fruits are packed as complete hands or clusters with 4-5 fruits or as single fruits (for institutions such as schools and hospitals).

Shipment

Bananas are extremely perishable having a rate of metabolism much higher than other fruits. To be available throughout the year, involves a streamlined transport system from the plantation packing station to the ships and then to the ripening rooms and finally to the markets. In all these movements the aim is to deliver the fruit to the ripening rooms in a firm green condition as free of blemishes as possible.

Boxed bananas leave the packing station by various means-railroad cars, trucks and refrigerated or non refrigerated containers. By whatever means they are loaded onto refrigerated ships within 24 hours after harvest or at the most 48 hours. The pulp temperatures is lowered to14-15°C as quickly as possible.

With the development of maritime transport insulation was greatly improved so that only 5 percent of the refrigeration is lost. About 43 percent of the refrigeration is for cooling and 21 percent for the heat of the respiration of bananas. Containers are usually not refrigerated until coupled to the ship's centralized refrigeration system. Containers are loaded within 10 hours of arrival at the wharf. Container ships ensure improved fruit quality and transit losses are less than 3 percent.

Quality standards

Quality standards help to assure the delivering of green fruit as free of blemishes and defects as possible and of a specified size and presentation. Size refers to finger length and thickness or grade. Presentation involves the size and arrangement of the cluster or hands.

Quality standards for fruits can be grouped in to five categories

- Fruit defects tolerated
- Minimum finger length
- Minimum and maximum grade
- Cluster size and arrangement
- Net box weight

Fruit defects include blemishes that affect the peel and pulp of which scarring and bruising are the most common and serious. They are classified as trace, light, medium and severe. Certain defects affecting the pulp, such as bruising are considered critical and given higher defect rating than blemishes affecting only the peel.

Fruit quality is evaluated at four levels

- As bunches before packing
- After packing prior to packing the ship
- At ship discharge
- After ripening

Bunches are examined on the cableways at the boxing plant or at dehanding locations, if bunches are dehanded in the field. Fruit quality in the box is evaluated immediately after packing at the packing plant or at the wharf prior to loading and at the discharge port. The final quality evaluation is made after the fruit is ripened in the ripening rooms. Fruit is ripened to average color 4 with a range of 3-5 using a 5-6 day schedule.

The following are the parameters for quality evaluation at the port of discharge and after ripening.

Physical defects (% clusters)	*After ripening fruit defects (% clusters)*
Bruises	Bruises
Latex stain	Crown rot
Neck injury	Latex stain
Neck rot	Neck injury
Scarring	Neck rot
	Scarring
	Mutilated fingers
Box conditions (% boxes)	*Physiological conditions (% boxes)*
Punctured tunnel pads	Ripes and turnings
Creased boxes	Underpeel discoloration
Crushed boxes	

Mechanical damage

Mechanical damage is one of the major factors leading to post harvest deterioration of plantain. It can occur from the point of harvest to point of consumption, adversely affect the appearance and increase potential for infection by diseases, resulting in lower market quality and price.

There are three main sources of mechanical damage to banana

a. *Impact*

Impact damage can result in bruising with or without skin rupture. Impact bruises are caused from a sharp blow such as an object falling on to the fruit or fruit falling against another fruit. Impact damage can occur throughout the marketing process. Injury is sometimes not immediately apparent but may show later.

b. *Pressure*

Pressure damage results from excessive pressure on the fruit. There is no need for physical movement for pressure damage to occur and happens primarily during and after packing as a result of forcing too much produce in to too small a container.

c. *Vibrations*

Vibration damage is mainly associated with transportation and results from repeated vibrations of the fruit. Vibration damage is severe in loosely packed fruit.

Pre harvest factors that contribute to mechanical damage include weather, wind, spraying, and fertilizer application, insect pests, birds, rodents and implements. In the harvesting process mechanical damage could result from poor harvesting and handling techniques. Soil adhering to the fruits art harvest can damage by scarring fruits. Post harvesting factors which can contribute to mechanical damage include over packing and under packing of fruits, poor packing and handling of packed fruits during loading and unloading.

Outcome of mechanical damage

- Physical changes in fruit color and flavor
- Softening of the fruit tissue, which results in the breakdown of individual cell walls.
- Damaged fruits generally ripen earlier than non damaged fruits. This is due to an increase in respiration rate associated with mechanical injury as well as an increase in the production of ethylene, which hastens ripening.
- Loss of fruit weight is another result of mechanical injury with obvious consequences of lower market quality and price. The weight loss is due to the breakdown of cell wall and increase in the permeability of outer cell layers to water vapour.
- Invasion by microorganisms, resulting in progressive decay which may affect the entire fruit.

Post harvest diseases

Post harvest diseases can cause serious losses of fruits both in terms of quality and quantity. The most important post harvest diseases encountered are dealt with below.

Crown rot

Crown rot is one of the most important post harvest diseases of banana/plantain. It is characteristically a disease complex caused by different fungi, sometimes in association with other microorganisms such as bacteria. The most common pathogens associated with crown rot are *Colletotrichum musae*, *Fusarium doxa roseum, Botryodiplodia ampara* and *Phomopsis sp.* When hands are cut from the bunch the massive open wound is an ideal weak spot for crown rot fungi to enter and grow.

Symptoms

- Softening and blackening of tissues at the cut crown surface
- White, gray or pink mould may form on the surface of the cut crown
- Infected tissues may turn black and the rot may advance to the finger stalk. Severely affected fingers may fall from the crown
- When severe, fingers will drop from the crown when suspended. Crown rot severity is highly unpredictable

Control

Control starts in the field with the regular removal of leaf trash. Proper sanitation can greatly reduce the number of crown rot fungi spores present. Do not keep rotting fruits or plant waste materials near the packing station. Maintain clean water in the delatexing tank frequently to stop it from becoming heavily contaminated with spores. Dehanding should be done with a sharp knife so as to avoid leaving a ragged cut. Finally post harvest treatment of fruits with an effective fungicide is essential.

Anthracnose

Anthracnose is another post harvest disease of banana and plantains. It is caused by the fungus, *Colletotrichum musae* which initiates two types of infection

a. The non- latent infection which occurs in small wounds, starting from harvest and continuing to develop thereafter without a dormant period .In green fruits anthracnose lesions are dark brown to black with a pale margin, lenticular in shape ,slightly sunken. The spots developing on ripening fruits are characterized by numerous small circular and brown to dark brown spots which coalesce to form large blotches.
As the disease progresses, the blotches become sunken with the centre covered with orange masses of spores

b. The latent infection starts early in the season when the fruits are still on the plant but the pathogen remains dormant as subcuticular hypha until the fruit approaches maturity. When the pathogen assumes activity on ripening, the infection causes the formation of typical dark brown spots on ripe fruits. It can also develop into destructive finger rots of green fruits in cold storage at 12-14°C. The disease common on injured peel is aggravated by bruises and wounds encountered during subsequent handling. Long storage and fluctuations in the storage temperatures favour anthracnose development.

Control

It is important to maintain strict hygiene in the plantation and pack house to minimize the number of spores available for infection. All cultural operations that reduce scarring and injury to the fruit will prevent anthracnose. Effective fungicidal treatment of fruits will help to reduce incidence.

Cigar end rot

The disease is caused by *Trachysphaera fructigena* and *Verticillium theobromae*.

Symptoms

Cigar end rot, which is essentially a plantain disease, affects fruit in their immature stages. The number of fingers affected in the bunch varies. The infection which starts with local darkening and wrinkling of the skin, originates in the perianth and spreads slowly backwards along the finger. The darkened area is bordered by a black band and a narrow chlorotic region, which separates infected and healthy tissues. The symptoms finally bear a resemblance to the ashy end of a burnt cigar.

Control

The principal method of control is frequent manual removal and burning of dead flower parts and infected fruits .Use of fungicide to control the disease is also recommended. Cigar end rot is effectively controlled by covering the flower after emergence with a polythene bag before the hands emerge.

Finger rot

Finger rot is caused by the fungus *Botryodiplodia theobromae* which invades the wound on the fruit skin. It penetrates the pulp and rots entire fingers and can pass to neighboring hands. Rotting finger ripens more rapidly and trigger premature ripening in an entire box.

Symptoms

Symptoms usually begin at the flower end of the finger or at a wound site. The decay spreads uniformly and causes a brownish black discoloration of the peel and softening of the pulp. The affected areas of the peel becomes wrinkled and encrusted with minute black bodies. The pulp is reduced to a soft rotten mass and a dark grey mould grows on the peel when the humidity is very high. Infected clusters tend to ripen prematurely and fully matured fruit is the most susceptible to infection.

Control

The disease can be held in check by minimizing fruit injury, by treatment of fruits with systemic fungicide and by rapidly reducing fruit temperature after harvest.

Use of fungicides

During the shipment of bananas in boxes the cut crown tissue is a major site for infection. Fungicides such as benomyl, imazalil, and prochloraz are approved for use in different countries. Fungicides are applied in different ways.

Another alternative to using conventional fungicides is to apply edible film forming polymers or other acceptable food additives eg. potassium sorbate and sodium benzoate. This technique can be useful in combination with low levels of fungicides oar as Experiments with papaya latex has prove defective for the control of crown rot or as part of an integrated control package. Experiments with papaya latex has proved effective for the control of crown rot.

Work carried out at Kerala Agricultural University

A study entitled Post harvest handling and packaging system for banana (*Musa* AAB) Nendran was carried out under a postgraduate thesis work (Nallamothu Gouthami, 2001) at the College of Horticulture, Vellanikkara. The summary of the results is given below.

Ripening

Treatments involving ethrel (vapour/dip) and smoke filling were found effective in enhancing the ripening of Nendran . However these treatments were on par in respect to their efficacy of ripening enhancement.

Ethrel (vapour/dip) recorded maximum score for overall acceptance. Nendran banana ripened in ethylene vapour-filled chamber recorded maximum score for appearance and flavour and those dipped in ethrel solution (1,000 ppm) recorded maximum score for taste (7.5 to 8). Smoke filling as a treatment for accelerated ripening of Nendran though effective, has disadvantages like smoky odour and poor appeal due to blemishes.

Precooling and storage

Storing Nendran bananas in ethylene vapour-filled chamber for ripening was found to be fast, easy, economic, and safe method. Precooling in cooled water (15°C) for 10 minutes / hot water (50°C) for 10 minutes followed by storage at 13°C improved marketability of Nendran. Precooling with ice flakes for five minutes followed by storage at 18°C improved marketability of Nendran. Nendran kept in open condition

from the storage environment of 13°C showed an increase in shelf life (6 – 7 days) over those taken from 18°C (5.3 to 6 days) and from ambient temperature (3 – 6 days). Nendran hands precooled with cold water (15°C) for 10 minutes/ ice flakes for 5 minutes / hot water at 50°C for 10 minutes and those stored with and without ethylene absorbent recorded more days to ripen when stored at 13° C compared to the same treatments stored at 18°C and ambient temperature.

Maximum storage life of 49 days with subsequent normal post storage ripening behaviour was observed in the storage of Nendran at 13°C in the presence of ethylene absorbent ($KMnO_4$). Storage with ethylene absorbent sachet reduced the PLW (Physiological Loss in Weight) and improved the marketability of Nendran banana in all the three storage temperatures studied namely, 13°C, 18°C and ambient temperature.

Nendran stored at 13°C recorded high acidity (0.56 % to 0.98%) when kept in open condition for ripening compared to those stored at 18°C (0.5 to 0.66%) and in ambient condition (0.41 to 0.61%).

Fruits ripened at 18°C and ambient temperature were organoleptically more acceptable than the fruits ripened after storage at 13°C.

Packaging

Of the different packages tried, ventilated (2%) polythene bag (100 gauge) and CFB (Corrugated Fibre Board) boxes improved the marketability of the fruits. Polythene lining and application of Waxol 12% to cut ends were effective in reducing PLW of Nendran compared to packing in CFB boxes.

Nendran hands packed with and without ethylene absorbent in unventilated polythene and vacuum packs recorded the lowest PLW over the other packages studied. Packing with ethylene absorbent resulted in lesser PLW over the package without ethylene absorbent.

Nendran banana hands packed in CFB boxes recorded the minimum days to ripening (7 days) while maximum duration was given by packing in vacuum with an ethylene absorbent sachet (42.67 days to ripen).

Nendran hands packed with and without ethylene absorbent in unventilated polythene bags (5.3 and 5 days respectively) and those packed in CFB boxes (6 and 6.3 days respectively) recorded the maximum shelf life and vacuum packed fruits with and without ethylene absorbent recorded lowest shelf life (3.33 and 3.67 days respectively) as a result of increased microbial spoilage.

Package in vacuum reduced the TSS, acidity, total sugars, reducing sugars and starch content of fruits, which were unacceptable on ripening. Nendran banana hands coated with Waxol 12% or Waxol 12% + Bavistin (1,000 ppm) at cut ends and packed in polythene lined CFB boxes were organoleptically superior to other treatments.

Grading

Guidelines to grade Nendran with hands as units, based on the number of fingers per hand, weight of hand, length of finger, girth of finger, curvature, weight, etc. revealed the possibility of grouping different hands.

Bunch of Nendran were grouped into four grades of A, B, C and D, the specification of which are as follows

	Grade A	Grade B	Grade C	Grade D
Length	23.0 cm	22 – 23 cm	20.5 – 22 cm	< 20.5 cm
Girth	12.5-13 cm	12 – 12.5 cm	11.5 – 12 cm	< 11.5 cm
Curvature	1.2-1.25	1.2 – 1.27	1.25 – 1.3	1.3 – 1.4
Hand weight	1500 –1,600g	1,250 – 1,500g	1,200 – 1,250g	1,000 – 1,200g
Finger weight	160-175g	140 – 160g	130 – 140g	110 – 130g

III. PROTOCOL FOR PRODUCTION AND TRIAL SHIPMENT OF BANANA Var. NENDRAN

Improved Production Technology

Cultivation Practices

Nendran as irrigated crop is planted during August to October while for rain fed crop, planting is undertaken during April-May. However studies have shown that under conditions of assured irrigation year round planting is remunerative.

Varieties

Chengalikodan, Nedunendran, Manjeri Nendran, Attunendran, Myndoli, Kaliethan, Kottayam Nendran are some of the clones extensively cultivated in Kerala

Planting material

Healthy, clean and disease free sword suckers, with broad base and tapering towards the tip are the best planting material. 3 - 4 month old suckers with rhizome diameter of 25 - 45 cm are selected for planting.

Tissue culture plantlets from known sources can also be used after proper hardening

Preparation of suckers

Nendran suckers are cut to a height of 15-20 cm from the rhizome and the roots and corm surface pared or trimmed. The suckers are then be dipped in a slurry of cowdung and ash and dried for 3 - 4 days. These prepared suckers can be stored for upto 3 weeks.

Land preparation and layout

Land is dug or ploughed properly to break clods and laid out adopting a spacing of 2x2m to accommodate 2500 plants/ha.

Method of planting

Planting in pits : The recommended pit size for Nendran is 50 x 50 x 50 cm. A small depression is made at the center of the pit to accommodate the sucker, which is kept firmly in place by pressing the surrounding soil.

Planting in channels : Channels of 45 - 50 cm depth, 50 - 70 cm width and desired length can be taken and suckers planted in rows

Manures and Fertilizers

At planting, apply organic manure as green leaves, compost or farmyard manure @ 10 kg per plant. 500 g lime per pit is also applied.

Where there is scarcity of organic manures cultivation of green leaf manure plants can betaken up in the interspaces. Sunnhemp, cowpea or daincha are sown at a seed rate of 50 kg/ha, about two weeks after planting of banana suckers. They can be ploughed and incorporated into the soil 40 days after sowing. A second crop may also be taken if there is sufficient moisture in the soil

The recommended fertilizer schedule for Nendran is NPK @190,115 and 300g/plant/year. The following application schedule may be followed.

Time of fertilizer application	***$N : P_2O_5 : K_2O$ g/plant***
One month after planting	40 : 65 : 60
Two months after planting	30 : 50 : 60
Three months after planting	30 : 00 : 60
Four months after planting	30 : 00 : 60
Five months after planting	30 : 00 : 60
Just after complete bunch emergence	30 : 00 : 00
Total	**190 : 115 : 300**

Fertilizers are applied in a circular band, about 30 - 60 cm away from the base of the plant and then mixed with soil.

Irrigation

Nendran variety is irrigated once in three days (twice a week) during summer months. A single plant requires about 45 litres of water during each irrigation.

Weed Control

During early stages of plant growth, complete control of weeds could be obtained by raising cowpea in the interspaces. In gardens where this is not possible, pre-emergence application of diuron 1.5 kg/ha or oxyfluorfen 0.2 kg/ha is effective. Weeds emerging later could be controlled by the application of paraquat 0.4 kg/ha or glyphosate 0.4 kg/ha. If hand weeding is resorted to, give 4 – 5 surface diggings depending on weed growth. Avoid deep digging. Do not disturb soil after plants start producing bunches. If green manure crop is grown, weeding operations can be reduced to 1 – 2 diggings.

Propping and earthing up

With the onset of flowering, propping is an essential practice to be followed in Nendran. Props must be firmly fixed into the ground at the base of the plants and the bunches tied to them.

Earthing up is done with the onset of south west monsoon for better anchorage and protection from water logging

Drainage

With the onset of South west monsoon, channels of about 20-30 cm depth are taken in between every 2 or 3 rows of plants to facilitate proper drainage.

Desuckering

Suckers arising from time to time must be destroyed until bunch maturation.

Pest Management

Pseudostem borer *(Odoiporus longicollis)* - This is a devastating pest of Nendran resulting in crop loss in the absence of proper management practices. Adult borers, which are black or reddish brown in colour, lay eggs on the pseudostem. Grubs, which emerge tunnel into the pseudostem and feed extensively. Small dark brown holes on the pseudostem are the first signs of attack, followed by gummosis or oozing of a thick jelly like fluid from these holes. Infestation usually starts from 4th month after planting but the symptoms are evident only by the time of flowering or later By this time, the pseudostem is completely damaged and the plant either produces very small bunches or collapses completely.

Management practices

- Keeping the field clean is of utmost importance. Affected and damaged plants must be promptly removed and properly destroyed. Dried leaves hanging around the pseudostem are cut and removed - this not only reduces chances of the pests hiding among them, but also enables to notice the symptoms in time and take suitable control measures.
- Swabbing the pseudostem with mud slurry or neem oil emulsion (made by mixing 1 litre neem oil with 10 litres of water using 50 g bar soap), especially on the border plants helps to reduce the egg laying by the pest.
- Upon noticing the signs of attack on any plant in the field, prompt spraying of the affected and surrounding plants should be taken up. Spraying carbaryl 4 g/litre or chlorpyriphos 4 ml/litre on the pseudostem is very effective in controlling the pest. Spraying can be done using rocker or knapsack sprayer, taking care to cover the pseudostem completely and also fill the leaf axils with the spray fluid. 4 - 5 plants can be covered using 1 litre of spray fluid. In highly prone areas, a prophylactic spray using any of the above insecticides should be given starting from the 4th or 5th month onwards. This should be repeated at 1 to 1½ month intervals for complete control.

Banana Aphid - They are small black insects found in colonies inside leaf axils near the base of the plant. They suck sap from the plants, but this does not cause significant damage. However, they may act as vectors of Bunchy Top Disease of banana.

Management measures

➢ Bunchy top affected plants must be promptly uprooted and destroyed completely along with the aphids. If the disease is severe, carbofuran application schedule must be followed to control the vectors. The schedule is : 20-25 g carbofuran at the time of planting (around the sucker in the pit) or after 15-20 days; repeating this at 75 and 165 days after planting with 25 g carbofuran in soil at the base of the plant or 12.5 g in the leaf axils.

Carbofuran application schedule is highly effective for integrated management of pests and nematodes in banana because of the systemic and persistent nature of carbofuran, combined with its broad spectrum action against insect pests and nematodes.

Rhizome weevil (Cosmopolites sordidus) - These weevils and their grubs, very similar to the pseudostem borer in appearance, cause damage by tunneling into the rhizome and feeding. Symptoms include yellowing and wilting of older leaves and finally, death of the spindle. Newly planted suckers as well as older plants are affected. On rhizomes presence of tunnels and large blackened decayed areas caused due to extensive feeding by the pest can be seen.

Management measures

➢Use only healthy clean suckers, free from lesions, tunnels or black decayed areas for planting. Keeping the field clean of plant debris and fallen pseudostem is also important as they act as hiding places for the pest.

➢ Paring and pranilage : Suckers selected for planting must be pared (surface peeled off) and then dipped in a slurry of mud/ cowdung or ash and then sun dried for 3-4 days before planting. This not only removes eggs or larvae of the pest present on the suckers, but also prevents further egg laying. Further, carbofuran granules may be sprinkled over the wet slurry before drying (pranilage) for better control of the pest.

➢ In highly prone areas, ratooning must be avoided as this practice facilitates breeding of the pest for long periods of time.

Leaf eating caterpillars - Several kinds of caterpillars are seen to feed on the leaves, the most common being *Spodoptera litura* and *Euproctis* spp.

Management measures

➢ When the caterpillars are very small, they are seen in groups scraping the underside of the leaves. At this stage, whole groups can be destroyed by rubbing the leaves together

➢ Later, when the caterpillars grow, they move and destroy larger areas. At this stage, spraying of insecticides like quinalphos @ 4 ml /litre will be required to control them. Spraying should be carried out during early morning or late evening hours, when the caterpillars come out to feed. During day time, they usually hide among fallen debris or in leaf axils. Hence, leaf axil filling with carbofuran or carbaryl @ 10 g per plant is also beneficial to control these pests.

Mealy Bugs - These insects are noticed in colonies, as white, fluffy material, sucking sap from different parts of the plant. Recently, mealy bugs attacking the roots of

banana were reported as a problem from several parts of the state. This attack resulted in yellowing, weakening and wilting of plants due to extensive damage to the roots and finally, even collapse of the plant.

Management measures

- Plants showing the above symptoms are examined for the presence of mealy bugs on the roots. If mealy bugs are present, the soil around the base of the plants are raked to expose the pests and then drenched with insecticides like endosulphan or dimethoate (3 ml/litre), using about 2-3 litres of fluid per plant.
- 15 days later, one more drenching using chlorpyriphos or quinalphos (4 ml/litre) may be given if the pests are still noticed.

Red Spider Mites *(Tetranychus* spp.) - These tiny red colored mites are seen in colonies on the underside of leaves, within a fine webbing. They feed on plant sap and this results in yellowing and drying of leaves.

Management measures

- If mites are noticed, a strong spray of water will wash them off at early stages of damage.
- Since they are not insects, mites must be controlled using acaricides, if the damage is serious. Dicofol @ 3ml/litre is effective for the purpose. The spray should reach the underside of the leaves.

Disease Management

Leaf spot Diseases - Sigatoka, Cordana and Freckle are the major types.

Sigatoka- This fungal disease occurs with the onset of the monsoons. Appearance of small, yellow, eye-shaped spots and lines on the older leaves. These enlarge and the center of the spots dry up. Later, entire leaves may dry up, resulting in reduction in yield due to loss of photosynthetic area.

Cordana- A fungal disease, characterized by appearance of large eye-shaped spots on the leaves with brown center, which coalesce and the entire leaf dries up.

Freckle- A fungal disease characterized by small, raised black spots on the leaves.

Management measures

- Control measures are initiated with the onset of south west monsoon.
- All the dried and diseased leaves should be cut and destroyed once in 3-4 weeks followed by spraying of fungicides such as carbendazim 1 g/litre, indofil M-45 3g/litre or calixin 1 g/litre on the leaves, taking care to spray on the underside of leaves.

Virus Diseases- Virus diseases are spread by insect vectors like banana aphids. Since the diseases have no cure, the only way to manage them is to control the vectors.

Banana Bunchy Top - Leaves are reduced in size, leathery and brittle and get clustered together resulting in a dwarf plant.

Banana Bract Mosaic / Kokkan-This virus disease is characterized by unusual reddish discoloration on the outermost leaf sheaths. Other symptoms include leathery texture of leaves, appearance of brownish streaks on the leaf lamina and midribs, separation of leaf sheath, leaves restricted to two sides only (traveller's palm

appearance), abnormal elongation of peduncle, delayed or no bunching and small and distorted bunches.

Other virus diseases - Mosaic (Infectious Chlorosis), Banana Streak

Management measures

- Select suckers for planting from healthy, disease free plants only.
- Uproot and completely destroy any diseased plant in the field after killing the vectors using kerosene, tobacco decoction or any insecticide.
- Adopt timely management measures to control banana aphids.

Rhizome Rot (*Erwinia caratovora*)

This is a bacterial disease, mostly seen in the rainy season and in poorly drained areas and also in banana cultivated in paddy fields. The disease is characterized by paleness and yellowing of leaves, followed by death of the spindle leaf. In two or three days, the diseased plant topples down. The base of the plant and rhizome of such plant show extreme rotting with foul smell.

Management measures

- Improve the drainage facilities in the field.
- Remove the diseased plants completely from the field and destroy. To prevent spread of the disease, apply lime in and around the affected pit.
- Avoid taking suckers from the affected plants.
- If noticed at early stages, drenching the base of the plants with fytolan @ 3g/litre is beneficial.
- Drenching the base of the affected and surrounding plants with streptocycline 3g / 10 litres / copper oxychloride effectively controls the disease and also prevents further spread.

Pre harvest operations

Debudding and dehanding

Snap off the male bud after the emergence of all the hands. Along with the male bud, any false hands with mixed male flowers and female flowers are also removed.

Bunch sleeving

Cover the bunches with a perforated(2%) polythene sleeve(white or light blue)and tied around the peduncle well above the first exposed hand

Tagging the bunches

After bagging, tag the bunch with colored ribbons to indicate the week bagged for scheduling the stage of harvest

Harvesting

Under optimum conditions, it takes 91/2-10 months from planting to harvesting in Nendran clones. Bunch emergence to harvest at full maturity takes 85-95 days. Harvesting the bunches at two maturity stages, viz 75% and 90% may be tried.

To harvest, remove the props, cut the stems to bring the bunch down, so as to rest on a padded tray, cut through the bunch stalk and carry the bunch to collection centers in stretchers or trolleys. The bunch should be handled without causing any wound, bruises and scratches.

Post harvest handling

a. Dehanding and delatexing

Harvested bunches are brought to the packing house for dehanding. Hands are separated giving a clean cut using a sharp cut knife. Removal of defective fruits is also done at this stage. Allow the cut surface to drain latex for 10 minutes.

b. Washing

Wash the hands in clean water taken in polythene tubs/tanks for 20-30 minutes for complete delatexing

c. Washing in alum solution

Disinfectant like alum solution is useful to prevent latex staining on fruits. Fungicides may be included as needed for controlling post harvest diseases. Thiabendazole, imazolil and benomyl are the commonly used fungicides for dipping at 300 – 500 ppm.

d. Packing

The treated hands are transferred to the packing area. After drying the fruits are subjected to modified atmosphere packing in Corrugated Fibre Board boxes with food grade plastic bags sheets of 100 gauge thickness. Boxes with a capacity to hold 13 kg fruits are suggested.

Packing may be done as hands or clusters of 4-5 fruits. A Nendran hand on an average weighs 1.5 kg. Individual rows of hands/clusters are separated by placing a protective tunnel pad. Care should be bestowed to avoid over packing or under packing. The ethylene absorbent, potassium permanganate may also be included in the packs to absorb ethylene from the bags.

e . Loading in containers and Precooling

The boxes containing the hands are loaded in containers. They are precooled to a temperature of 13°C.Precooling should ideally be done within 24 hours from harvest. To prevent chilling injury, the temperature should not go below 13°C.

f. Transportation in reefer at 13-14°C

g. Increasing the temperature to 18°C at destination

h. Ripening

Ripening the fruits in ripening rooms by ethylene treatment at 1000 ppm at 18°C and 95%relative humidity for 24 hours. For ripening following a 5 day schedule ventilate for 20- 30 mins daily for 5 days by which time the fruits are expected to reach stage 4 and are ready for marketing.

i. Holding of ripe fruits at 13-14°C and marketing.

Quality evaluation after ripening

During ripening banana undergoes many physical and chemical changes that determine the quality of fruits purchased by the consumer.

Physical Parameters

The following are recorded-bruising, scarring, crown rot, latex stain, off color, neck injury

Assessment of changes during ripening

Peel and pulp color changes

The disappearance of green color and corresponding increase in the yellowing of peel during ripening are obvious manifestations. Classify fruits according to peel color by visually matching the peel color of fruits against a color chart. Color measuring devices could also give a good indication of the changes during ripening or stage of ripeness of the fruit.

Conversion of starch to sugar

The most striking post harvest change which occurs during the post harvest ripening of banana is the hydrolysis of starch and accumulation of sugar .In plantains this breakdown is slower and less complete and continues in over ripe and senescent fruits. For this, the starch iodine test, which is a simple, rapid and inexpensive method, could be employed.

Changes in pulp to peel ratio

Peel to pulp ratio is a good consistent index of ripening of banana. Pulp to peel ratio increases in response to ripeness, which is related to sugar concentration in the two tissues. Pulp and peel are separated, weighed individually and expressed as pulp to peel ratio (pulp weight divided by peel weight).

Changes in pulp firmness

Under normal storage conditions, bananas undergo significant textural transformation as they pass through the ripening process. The crisp, hard and green fruit turns in to a yellow fruit with tender and soft pulp at the optimal ripening stage. Loss of firmness during ripening leads to lower quality and higher incidence of mechanical damage during handling and transportation.

An indication of firmness is obtained by the force necessary to cause penetration of a standard probe within a specified distance in to the product. Hand held penetrometer is used for measuring pulp firmness.

Change in total soluble solids content

During ripening of banana, the total soluble solids content increases. Sugar forms the main component of soluble solids and can be a useful index of ripeness. The most

popular method of measuring total soluble solids content is to measure the refractive index of the juice using a refractometer.

Changes in pulp pH and total titrable acidity

Pulp pH and total titrable acidity are important post harvest quality attributes in the assessment of fruit ripening quality. In general there is a rapid decline in the pulp pH in response to increasing ripeness. The pulp pH could be used as an index of ripening. The pH value of the filtrate from pulp samples is determined using pH electrode. Acidity measured as titrable acidity in the pulp tissues of most bananas show large increases during ripening or as ripening progresses. Therefore titrable acidity could be used as an index of ripening. Total titrable acidity of pulp samples is determined by titration of the sample with sodium hydroxide to the phenolphthalein end point and calculation o f acid present as malic acid

Change in pulp and peel moisture and dry matter content.

During ripening moisture content of the peel decreases whereas that of the pulp increases. The dry matter of the peel and pulp does not increase significantly during ripening.

Moisture content (%)- wet weight-dry weight x (100 x wet weight)

Dry matter content (%)-100_(% moisture content)

Sensory quality

Sensory analyses give a total impression of aroma, taste, temperature, auditory and tactile components and thereby give an indication of the potential for consumer acceptability of the fruits. A questionnaire has to be designed for the purpose

VARIATION IN BUNCH MORPHOLOGY OF NENDRAN

PROPPING TO PROTECT FROM WIND DAMAGE

BUNCH SLEEVING

MAJOR DISEASES OF NENDRAN

Sigatoka Leaf spot

Banana Bract Mosaic (Kokkan)

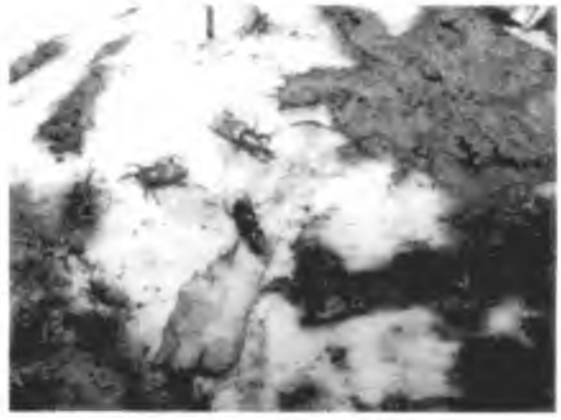
Banana Bunchy Top

Banana Streak

MAJOR INSECT PESTS OF NENDRAN

Pseudostem borer

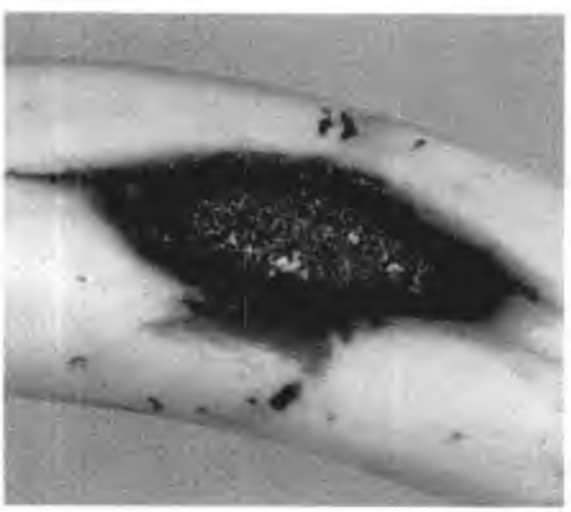
Rhizome Weevil



Leaf feeding caterpillar

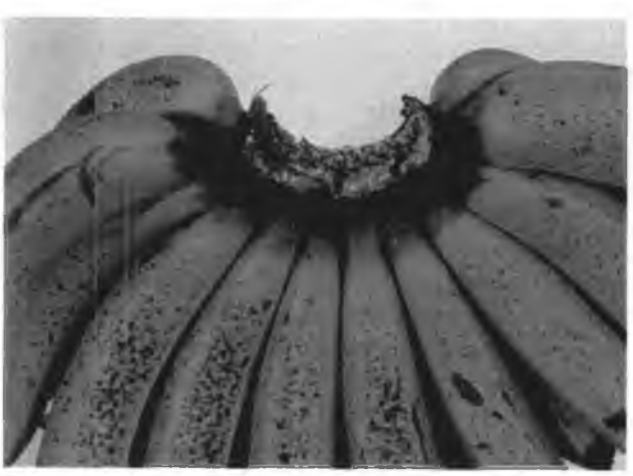
POSTHARVEST DISEASES

Anthracnose



Cigar End Rot

Crown Rot



Stem End Rot