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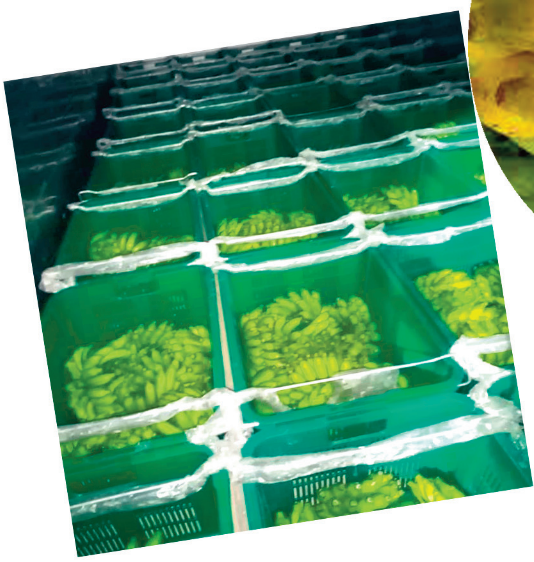
ASMP
Agriculture Sector Modernization Project

OPERATIONAL MANUAL

AMBUL BANANA

AGRICULTURE SECTOR MODERNIZATION PROJECT



A PARK
AGRICULTURE TECHNOLOGY DEMONSTRATION PARK

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Message from Project Director

Sri Lanka takes great pride in its rich heritage, with a written history that spans thousands of years. Its fertile soil, diverse landscapes, and strategic location have long made it an ideal hub for farming.

While agriculture evolved globally, Sri Lanka faced challenges. The industry became less profitable and labour-intensive, compounded by the introduction of an open economy. The fragmentation of cultivable land into small, inefficient plots further compounded the challenges as farming was no longer seen as a reliable career.

Sri Lanka allocates a significant portion of its foreign exchange on importing agricultural commodities. Recognizing the potential of its nutrient-rich soil, the government saw an opportunity to cultivate crops that meet international demand while reducing imports and boosting foreign exchange through exports. To capitalize on this, the government prioritized advanced agricultural technologies. In 2017, the "Agriculture Sector Modernization Project" (ASMP) was launched with the World Bank funding.

The project focused on areas where Sri Lanka had the most potential, such as export-oriented tropical fruits and vegetables . It started pilot project in year 2018 with World bank funding with seven districts in five provinces (Jaffna, Mulaithevu, Batticaloa, Anuradhapura, Polonnaruwa, Mathale and Monaragala) and expanded with the grant of the European Union, in another five districts (Kilinochchi, Vavunia, Ampara, Kandy, Badulla) (Kilinochchi, Vavunia, Ampara, Kandy, Badulla) The project secured a loan of USD 64 million from the World Bank, along with a grant of USD 25 million from the European Union. To date, the project has generated USD 65 million in foreign exchange earnings, with potential savings of up to USD 3 million domestically.

The project focused to high-demand tropical fruits and vegetables. Small farms were consolidated into larger groups of 300 to 400 entrepreneurs into Agriculture Technology Demonstration Parks (ATDPs) and modern technologies were introduced.

Tropical Fruit varieties are the main crops selected for Agriculture Technology Demonstration Parks of the Agriculture Sector Modernization Project (ASMP) by the International Service Provider (ISP) identified as Tropical Queens (Banana, Mango , Guava, Papaya and Pomegranate) which are among the most popular fruits in the world. ISP engaged in producing those competitive and marketable commodities for both local and export markets

The socio-economic problems and the COVID pandemic of the Country during year 2020- 2022 affected the implementation of the ISP technology packages. Because of this, the ISP and the ASMP developed optional technology packages, designed to overcome the shortfalls of the crisis. Procurement of equipment and supplies already available in the Country was given priority to avoid import delays and constraints. Different irrigation systems were used when the preferred system was not available. Options are also being developed for inputs such as fertilizers and pesticides. Intercropping was implemented as the ideal weed control practice and staple food crops to provide much-needed food to the Country. More emphasis is given to IPM systems to control pests and diseases. Even existing crops were given pre- and post-harvest technology to start exports without waiting until newly planted crops are harvested. Therefore, most of ASMP crop clusters have both existing crops and new crops with complete ISP technology package. Therefore, the Operational Manuals of Dr Julian; the Agronomist of ISP are based on technology for both existing crops of farmers as well as new crops with entire technology package .

ASMP started with Pilots by introducing Department of Agriculture (DOA) technology. With the intervention of Dr. Julian, ASMP involved in Vertical upliftment of the existing DOA technology from land preparation to pre / post-harvest technology to end up with modern processing technology with reefer container protocol for export which have never been practised in Sri Lanka . High density double Row planting, Low pressure irrigation (mini sprinklers, Drip tapes), irrigation based on mini whether station data , soil test based fertigation, modern training and pruning of fruit trees (box and espalier), use of poly mulch , pre and post- harvest Technology (use of colour bagging , colour ribbons, fruit desk etc) are some of the promising technologies introduced by the ISP. ASMP has produced Operational Manuals for Banana (Ambul, Kolikuttu, Cavendish), Mango, Guava , Papaya, Soursop, Passion fruit, chilli, Vegetables , Jumbo peanut, potato , Red onion and Maize .

The project introduced innovative methods for increasing land productivity. Techniques like high-density double-row planting and the "espalier" method allowed agroprenuers to double or even triple their yields. Automated water-controlling systems based on weather station data ensured a effective use of water supply, enhancing productivity reducing use of fertilizer. Solar energy was harnessed to power these systems, reducing reliance on the main electricity supply..

Over the past seven years, the project had transformed the concept of "farming" in Sri Lanka. Once viewed as an unattractive profession, farming had become a thriving opportunity, attracting the new generation. This shift had marked a major change in societal attitudes and had empowered farmers as agropreneurs, driving innovation and growth in the agricultural sector.

A key initiative of the project was the transition from individual farming to the establishment of farmer companies. Farmers were organized into "Public Unlisted Companies (PUC)," raising the status of farming from a mere livelihood to an esteemed profession. This shift established a structured system, elevating agriculture to a professional level and instilling a sense of pride in the farming community.

Farmers of the Agriculture Technology Demonstration Parks of the Agriculture Sector Modernization Project (ASMP) were organized into Farmer Producer groups and these groups were later registered as Farmer Companies under the Companies Act No 7 of 2007, in the Public Unlisted Company category. There are 59 Farmer Companies already functioning in the ASMP crop clusters.

The Farmer Company model facilitated direct business transactions between local farming organizations and international buyers, creating new global business opportunities

Specialized processing centres for each Farmer Company ensure that crops are processed, graded and packaged according to international standards. This system provides the buyers with access to high-quality products through a structured, well-organized, and accountable framework, ensuring benefits for both agropreneurs and buyers alike.

Dr. Rohan Wijekoon
Project Director
Agriculture Sector Modernization Project

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1. INTRODUCTION

The banana is the largest plant in the world without a woody stem. Is made up of fleshy, upright stalks topped with soft, smooth arching leaves. The banana belongs to the Musacea family, genus *Musa*. It is a flowering plant that produces fruits in bunches. Bananas are native to Southeast Asia.

1.1 Optimal Ecological Requirements

- Altitude 0 m – 1,000 m above sea level.
- Rainfall from 1,500 mm to more than 3,000 mm annually.
- Optimum Growing Temperature 26 ^{0}C – 28 ^{0}C
- pH range 5.5 – 7.5.

They grow best in the tropics and can be found in plantations in a wide band between 30 degrees north and south of the equator.

The soil should have good drainage, adequate fertility, and moisture. Deep, rich loamy and silty clay loam soils are most preferred for banana cultivation. Drained, poorly aerated, and nutritionally deficient soils are not suitable for bananas.

2. LAND PREPARATION

2.1 Primary Land Preparation

1. Deep ploughing using a 60 cm diameter disk plough.
2. Incorporation of organic matter/ Lan Commercial Compost by broadcasting 12 MT per hectare or 5 MT per acre of compost
3. Deep plough again perpendicular to the first pass

2.2 Secondary Land Preparation

1. Heavy Soil Textures
    a. Disk harrow using a disk harrow implement with disks having a diameter of 40 cm.
    b. Two passes perpendicular to each other are required.
2. Light Soil Textures
    a. Cultivate using a tine tiller implement.
    b. Two passes may be required in sandy clay loam soils.

2.3 Tractor

1. Tractor size 75 to 99 HP (75 to 85 POT), four-wheel drive

2.4 Drainage

1. Light Texture Soils
    a. Sloping handmade ditches to evacuate water from rainfall quickly 30 cm wide x 15 cm deep.
    b. These ditches will discharge into a larger sloping drainage trench 75 cm wide with a depth between 45 cm to 60 cm according to the conditions of the land.

c. This is a "U" type drainage design for small plots made up of two lateral drainage ditches at the extreme ends of the plot that drain into a primary drainage canal that evacuates the water away from the plot.
d. Before making the ditches, it is necessary to observe the slope of the plot and the East-West direction of the double row planting. Ideally, the double rows should drain into the lateral ditches without much effort.

2. Heavy Texture Soils
   a. Sloping drainage secondary canals 45 cm wide x 30 cm deep at 20 m intervals
   b. These canals will discharge into a larger primary type sloping drainage canal 1 m wide with a depth of 60 cm according to the conditions of the land.

3. Waterlogged Soils
   a. Drainage lines 45 cm wide and 45 cm to 60 cm deep at 5 m to 10 m intervals
   b. These lines will discharge into a larger primary type sloping drainage canal 1 m wide with a depth of 60 cm according to the conditions of the land.
4. Drainage Equipment
   a. Backhoe Excavator or similar with 30cm or 45cm wide bucket

3. VARIETIES

The Agriculture Sector Modernization Project banana varieties are Ambul, Kolikutto and Cavendish. Ambul and Kolikutto are local small banana varieties and are for export purposes, whereas Kolikutto is for the local market.

4. PLANTING MATERIAL

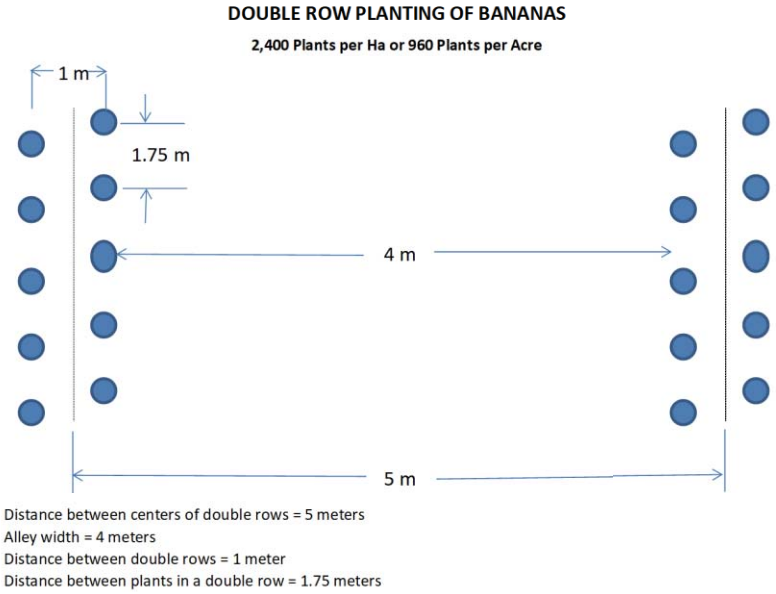
For Kolikutto and Cavendish, tissue culture meristems are used as planting material. They will be procured from local nurseries qualified by the Project to supply the optimal planting material (Annex 1).

For Ambul bananas, the planting material will be peepers collected from selected mother plants and grown under nursery conditions for at least 3 months by the farmers (Annex 2).

5. HIGH DENSITY DOUBLE ROW PLANTING

5.1 Procedure

For planting purposes, all distances are carefully measured and staked out in the field in order to achieve the population density as precisely as possible. An East-West orientation of the double rows is recommended to maximize the sunlight exposure of the fruit trees in the double rows throughout the day.



At the beginning, an origin or initial point is chosen at one end of the field making sure that there are no obstacles and no shading on either direction that can affect the development of the crop. A base line facing East or West is then laid out at one end of the plot from the origin. A second base line perpendicular to the first base line is drawn as well. The first double row is measured at 1 m on the East-West base line and layout by measuring 1m at 5 steps intervals down the row from the base line. The 4 m width of the first double row alley is then measured from the second row of the first double row. The alley is then laid out by measuring 4 m widths at 5 steps intervals down the row. The rest of the double rows and alleys are measured, and layout based on this initial double row and alley way using 1 m and 4 m widths.

The planting distances are measured on each double row laid out making sure a triangular or zig zag pattern is achieved within the double row. To achieve the zig zag pattern, the planting distances in the second double row begin being measured at half the planting distance from the origin of the base line.

Once the double rows and alleys are laid out and planting distances marked with wooden stakes, planting begins in the first double row established at the base line. All other double rows are planted as laid out from the first double row on the chosen base line.

Once the planting distances in the double rows are measured and delineated, planting holes are excavated of sufficient size and depth to accommodate the size of the bags containing the planting material coming from the nursery. The small plants are then placed in the planting holes without the plastic bags, but with the potting mix still attached to minimize transplant shock. The soil is then firmed around the new transplant to increase the anchorage of the new plant in its new environment. It is important to flatten out the soil around the newly planted meristem to avoid basins that may cause waterlogging around the new plant.

Water must be applied as soon as possible after the transplanting operation is completed. Water must continue to be applied throughout the growing period of the banana plant as required depending on rain fall.

5.2 Plant Spacings within the Double Rows

Bananas	**1.75 m**

5.3 Planting Aids

1. Construction twine (preferably white coloured)
2. A good number of wooden stakes to layout base lines and double rows
3. Right angle template made out of a non-stretching rope with marks at 3 m, 4 m and 5 m.
4. Template of 1 m in length to confirm width of the double rows, made out of a non-stretching rope.
5. Template of 4 m in length to confirm width of the alleyways, made out of a non-stretching rope.
6. Planting stakes to mark planting holes (good quantity)
7. Spade type shovels to make planting holes (30 cm x 30 cm x 30 cm or one cubic foot planting hole for bananas

5.4 Pictorial Guide

Laying Out the Base Line

Delineating the Double Row

Making the Planting Hole

Placing the Meristem in the Planting Hole

Watering after Planting

Establishing the Double Row

6. IRRIGATION AND FERTIGATION

6.1 IRRIGATION

Bananas require 9 mm per day of water for optimum production. Low pressure irrigation is the best method of applying uniform and precise amounts of water directly to the root zone of the plants, as per their above requirement, through emitters at frequent intervals over a period, via a pipe network comprising of mains, submains, and laterals. In this system, water is applied drop by drop or by micro jet (micro sprinkler), on the soil surface or below it (sub-surface), at a rate lower than the infiltration of the soil.

Micro sprinkler systems (micro jets) are preferred for fruit trees because the hydraulic head created by their height and discharge rates will push the waterfront downward in the soil profile to reach their deeper root systems of fruit trees.

Figure 1: Advantages of low-pressure irrigation

6.2 New Irrigation Concepts Introduced by the International Service Provider (ISP)

- Net Area Irrigation – Water for Cultivated Area Only
- Evapotranspiration for irrigation scheduling rather than soil moisture content
- Consumptive Water Use by Crops: Different Crops Different Amounts of Water
- Water Amounts Are Adjusted to The Physiological Development of the Crops (Kc Constants per Crop)

6.3 Water Application

The banana consumptive water use of 9 mm of water per day is equivalent to 63 mm per week. This weekly amount can be applied in 3 cycles. Under this application regime, the chart below is the recommended irrigation time per cycle to irrigate bananas using the ASMP micro sprinkler system:

Table 1: Water Application Schedule

Irrigation Schedule	1-3 months		4-12 months		One Year +	
Irrigation Time (Hours/ Minutes)	1	13	1	42	2	10

6.4 FERTIGATION

The banana plants require high amounts of nutrients because of the large biomass they produce in a production cycle. That makes bananas heavy feeders, meaning they extract large quantities of nutrients from the soil to produce optimum yields. It is also a very well-known fact that bananas fingers have very high Potassium (K) content. In fact, athletes use bananas to replenish electrolytes lost in competition. This also means bananas require high amounts of Potassium.

In general terms, the right kind of nutrition must be provided for quality and quantity production, and this involves the supply of both macro and micronutrients. Macronutrients include Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur. They are needed by the plant in relatively higher quantities. Micronutrients are required in low amounts and include Copper, Iron, Zinc, Manganese and Boron.

These nutrients can be supplied through basal fertilizers and foliar feeds application. However. Fertigation is the most efficient way to apply fertilizers because the nutrients move quickly, reaching the roots of the plants fast, allowing for a rapid uptake by them in a very short period.

Application of manure is necessary for soils with little or no organic matter. It releases its nutrients slowly throughout the growing period and adds organic matter to the soil.

Soil testing is required before planting as it helps in determining the fertility level of the soil.

The fertilizer application in the ASMP Clusters is based on soil test results. Annex 4 contains all the soil tests and the global fertilizer recommendations for the banana Clusters. The results of the Rajanganaya, Anuradhapura tests below will illustrate the process followed to formulate a fertigation program for bananas:

The results of the Rajanganaya soil tests indicated the following:

Potassium (K) is very low in 4 out of 5 sites
Copper (Cu) is deficient in 4 out 5 sites
Zn very deficient in all sites
The Ca/Mg ratio very narrow in Favor of Mg
Ca/K ratio narrow in two sites
Mg/K ratio generally high in Favor of Mg
The cation ratios show the exchanged complex is unbalanced against Ca and K, requiring supplemental applications of Ca and K. Ca as a soil amendment and K both as a nutrient and soil amendment

The recommendations for the application of fertilizers for this soil test are as follows:

Nitrogen (N) to be applied as required by the banana crop
Applications of (Potassium) K are required both for low K and for cation unbalances, except for Track 5
Foliar micronutrients must be applied, primarily Copper (Cu) and Zinc (Zn). Specially Zn is required
Applications of Calcium (Ca) as CaSO4 as a soil amendment are required to increase the Ca/Mg ratio. The SO_4 will also provide Sulphur (S) and will lower pH making other soil nutrients more available for the banana crop

In the case of applications of Potassium, the most important banana nutrient, the amount to be applied is calculated using the lowest level shown in the soil test, 0.3 milliequivalents (meq) per 100 gm of soil, as a reference.

According to scientific literature, Fruit trees, in general, need a soil test level of at least 1 meq of the major soil cations Calcium, Magnesium and Potassium for optimum production. The soil in Rajanganaya, therefore, is lacking about 0.7 meq of Potassium (1 meq – 0.3 meq = 0.7 meq).

This required level of Potassium (0.7 meq) can be converted to an application rate of 550 Kg/Ha using soil fertility conversion factors as follows:

- First, it is necessary to convert meq to parts per million (ppm's).

- It is worth noting that the soil test unit for Cations is meq/100 g of soil and that ppm is mg per Kg.
- Thus, the conversion factor from meq to ppm is the chemical equivalent weight of the nutrient (Potassium), which is 39, times 10. The result is 1 meq = 390 ppm.
- Then, to convert ppm to Kg/Ha, the ppm's are multiplied by 2 taking into account that ppm's are per million weight and that 1-hectare furrow slice of soil weighs 2,000,000 lb. In other words, parts per 2 million.

Therefore,

- If 1 meq of Potassium is 390 ppm, then 0.7 meq of Potassium are 273 ppm (390*0.7).
- This value of 273 ppm of Potassium are, then, multiplied by 2 to give 546 Kg/Ha. To obtain a practical number, 546 Kg/Ha is rounded off to 550 Kg/Ha.

The amounts of other major nutrients (Nitrogen and Phosphorous) required are obtained from research data. If such data is not available, amounts are taken from the literature or from experience in other production areas.

Foliar applications of micronutrients are recommended weekly if the soil test values are below the critical levels established for micronutrients in the scientific literature.

Supplemental amounts of Calcium (Ca) and/or Magnesium (Mg) may be applied based on the Cation Exchange Capacity, the Calcium Saturation of the soil and the cation ratios calculated from the soil test. In the case of Rajanganaya, the Ca/Mg ratios from the soil test were very narrow (low) in favor of Mg. The actual values were close to 1 and according to the scientific literature, the Ca/Mg ratio must be 10 to 15. In this case, applications of supplemental Ca are recommended.

Based on the above considerations, the amounts of nutrients to be applied for bananas in Rajanganaya are:

Recommendation	N	P	K	Ca
Kg/Ha	400	55	550	100
Lb/ acre	400	55	550	100
Kg/ Acre	181.8	25	250	45.5

For the above nutrients amounts, the chosen fertilizers, and their quantities per year (season) are:

Kg/ Acre	Urea	P Acid	TSP	MOP	$CaSO_4$
Fertilizer per Year (Season)	395	29	27	502	207

Considering the stage of development of the crop, the fractions to adjust the quantities of the above fertilizer materials to be applied at the different stages of development of the crop per season are:

Ratio Based on Tree Age	1 to 3 Months	4 to 12 Months	One Year +
Urea	0.50	0.75	1.00
P Acid	0.50	0.75	1.00
TSP	0.50	0.75	1.00
MOP	0.50	0.75	1.00
$CaSO_4$	0.50	0.75	1.00

The fractions adjust the amounts of fertilizer material to the actual quantities to be applied according to the physiological development of the crop.

Kg/Acre	1 to 3 Months	4 to 12 Months	One Year +
Urea	198	296	395
P Acid	14	21	29
TSP	14	20	27
MOP	251	377	502
$CaSO_4$	103	155	207

In a crop year in Sri Lanka, the number of irrigation weeks is 26 weeks. The rest of the year, rainfall is enough to satisfy the water requirements of the banana crop. Therefore, the amounts of fertilizer required per week are:

Kg/Acre/Week	1 to 3 Months	4 to 12 Months	One Year +
Urea	7.6	11.4	15.2
P Acid	1.1	1.7	2.2
TSP	0.5	0.8	1.0
MOP	9.7	14.5	19.3
$CaSO_4$	4.0	6.0	7.9

These amounts are to be applied in two cycles per week. On a a per application basis (irrigation cycle), the amounts of fertilizer materials required are:

Kg/Acre/Application	1 to 3 Months	4 to 12 Months	One Year +
Urea	3.8	5.7	7.6
P Acid	1.1	1.7	2.2
TSP	0.3	0.4	0.5
MOP	4.8	7.2	9.7
CaSO4	2.0	3.0	4.0

These amounts are further reduced based on the net area cultivated in bananas. For a production plot with size of half an acre, the net area to be fertigated is only 0.11 acres. Following are the fertigation recommendations for this net area:

Table 2: Fertigation Recommendations per Application and per Half Acre Plot

Kg/ Sub-Plot A/ Application	1-3 Months	4-12 Months	One Year +
Urea	0.42	0.63	0.84
TSP	0.03	0.04	0.06
MOP	0.53	0.80	1.06
$CaSO_4$	0.22	0.33	0.44
Applications per Week	2		
Phosphoric Acid (ml)	71.9	107.9	143.8
Foliar applications of micronutrient every two weeks			
Do not apply MOP in track 5. Need to continue monitoring K level through soil and foliar analyses.			

7. WEED CONTROL

The best weed control practice is intercropping. Not only it will control undesired weeds, but it will also generate income for the farmers. In the absence of intercropping, only mechanical weed control practices are to be used. Herbicides are not allowed to be used. The most common mechanical weed control practices are:

1. Cultivation with a tractor using a rotavator implement.
2. Motorized weed cutters that use plastic cords to cut weeds (weed eaters)
3. Workers using bush knives or any other cutting or chopping tool.

8. MAT SANITATION

All dry matter hanging or clinging from the banana plant, including old bent leaves, must be removed quickly to reduce the risk of diseases and pests, especially Black Sigatoka (BLS) and the bunchy top virus (BBTV). The load of other causal agents that cause pre- and post-harvest diseases, such as fungal spores and bacteria, is also drastically reduced by keeping the plants clean. It is also important to make cuts upward and flushed with the pseudo-stem with very sharp cutting tools such as bush and short knives to avoid dry "ears" that hide and harbour pathogens and insects. This work must be done religiously on a weekly basis without exception.

All dry matter must be removed from the Plants

Plantation free from hanging dry matter

Mat Sanitation Practice

9. PRUNING (DE-SUCKERING)

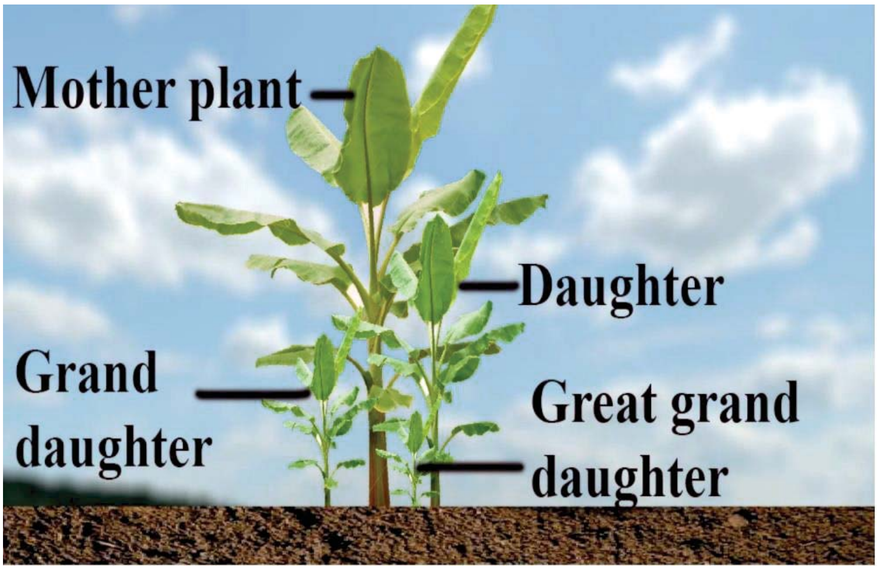


Figure 2: The Banana Production Unit: Mother, Daughter, Grand-Daughter

The most important operation in banana cultivation is the pruning (removal) of unwanted suckers in order to create and maintain a production sequence based on the family made up of the mother, one single daughter and one single granddaughter. This is known as a production unit in banana jargon. The difference in height among vigorous members of the family establishes the ratooning rate of the plantation, known as return, which is measured in terms of the number of bunches a unit or family is capable of producing per year. Since pruning involves the removal of unwanted suckers, the person doing this task can either destroy, retard, or accelerate the ratooning rate, making a very significant impact on the productivity of the plantation. Obviously, the aim of this practice is to accelerate or enhance the ratooning rate and the production of banana boxes for the market rather than numerous individual fruit stems. It is more efficient to produce more than one banana marketable box per bunch than use several bunches to produce one box. This is known as the box/stem ratio and is a measure of productivity.

The pruning practice has two components, vigour, and position. Vigorous followers or suckers grow faster and produce big and better bunches. However, the population density and the distribution of the followers within the plantation to maximize the penetration of sun light and diminish competition with other followers, depends on the positioning of followers. Therefore, sometimes vigour has to be sacrificed for position. These components demand that the labourer doing the practice becomes aware of the population and vigour situation all around (360° degrees) the affected production unit in a traditional plantation. In the double row planting system, the position priority is to maintain the double row before selecting for vigour. This is known as 180° degree pruning. In addition, all followers born and developing inside the double row must be eliminated. In a practical sense, double row pruning is easier in double rows, but the sacrifice of vigour is greater, especially in the first pruning cycles.

The pruning cycle is 6 to 8 weeks and must be done before fertilizing and population adjustment. Only followers that are 40 cm tall should be chosen. At this stage of development, it is easy to determine the vigour and the position of the suckers to be pruned. Very sharp special long bush knives, cut off at the tip, are used for pruning purposes to avoid damaging the mother plant and the selected followers. Cuts must be made deep enough to separate the followers from the mother plant and then they are

Types of Suckers

(a) deep-seated sword sucker

dislodged from the inside out. All soil material removed or disturbed must be returned to the cut and must be pressed again to seal the cut.

Figure 3: Proper Pruning - One Mother/ One Follower

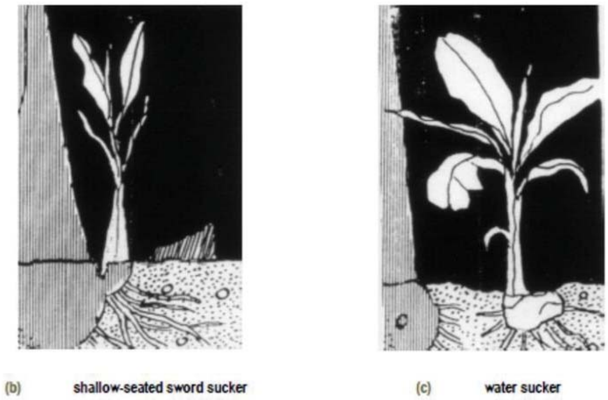


Figure 4: Deep Rooted Sword Suckers Are the Best for High Productivity and Ratooning Rate

Figure 5: Pruning Errors

Figure 6: Proper Pruning Assures an Optimal Production Sequence (Ratooning Rate) for High Productivity

10. POPULATION ADJUSTMENT

The population density and proper distribution of followers must be maintained at all costs in the banana plantation; however, field losses of members of the family and pruning mistakes do occur. The transplant of neighbouring plants or suckers is the most common way to address these problems. Since bananas are propagated vegetatively, plants and/or followers of any age and size, with or without followers attached, can be moved to the right places by mechanically lifting them carefully from their original place and moving them to a place nearby that needs a population adjustment. When followers are attached to the transplants, the transplant must be placed in such a way as to allow the follower to point towards the best distribution spot in relation to neighbouring plants.

The size of the transplant follower must be chosen to match the height and vigour of the surrounding families. It is not good a good practice to transplant a very small follower if the families around are vigorous and tall. Care must be taken also to avoid placing a small follower in a shady area. The ratooning rate will be drastically reduced.

Transplants for population adjustment will produce smaller fruit bunches, but the suckers and followers of the transplants will be very good and vigorous. One must remember that this practice is for adjusting the population density and correcting distribution problems. The impact of this practice is therefore not immediate but will take place when followers from transplants produce fruit.

Tools, such as very sharp and flat digging shovels and long bush knives, are used to carry out this practice.

Mid-Size Follower Being Removed

Follower Going to New Place

Follower Planted in New Place

Tall Mat Transplant

Mat Has a Nice Follower

Mat with Follower Moved

Follower Transplanted into Double Row is Smaller than Neighboring Plants, a Condition that Will Delay the Ratooning Rate of the Transplant

11. PROPPING, GUYING AND AERIAL CABLE

As the banana bunch matures, it becomes susceptible to losses caused by loss of root anchorage from nematode damage, the weight of the bunch itself and by wind. There are three ways to prevent these bunch losses: wooden props (propping), plastic twine guys (guying) and aerial cables.

A banana prop is two poles separated loosely by a piece of rope 2 cm (0.8 inch) in diameter tied securely to each pole. The length of the poles should be according to the banana varieties in the plantation. For the tall Williams, the wooden poles should be 3.6 m (12 ft) long. For the shorter Asdia and Apollo, the poles should be 2 m long. The thickness should be 3 cm to 5 cm to support the bunch until it is harvested. This prop is placed underneath the bunch and against the pseudo-stem right below the leaves, taking special care to avoid damage to the fruit. After placement, the poles making the prop are separated forming at least a 30o angle to maximize their strength. This practice can be done on a weekly or bi-weekly basis, making sure the bunches are protected while still young and light. The wooden propping poles can be re-used several times until they become non-viable.

Propping is a good practice to provide support during stormy weather with high winds and small cyclones. The main problem is to secure a steady supply of poles without cutting large portions of forest down. In other countries, bamboo is used as poles and a bamboo plantation is established to supply poles to the banana plantation.

A Prop is Two Poles Tied Loosely Together

Props Are Placed Right Below the Leaves in the "Neck" of the Plant

The Right Pole Length Provides Strong Support

Guying is accomplished using plastic twine with a thickness of 0.5 cm (3/16 inches). A portion of the twine is cut of sufficient length to make a loop around the banana pseudo-stem right below the leaves (neck) and long enough to use the neighbouring plants as the guy. One of the loose segments of the twine is looped again near the base of the pseudo-stem of the guying neighbouring plant at a height of approximately 50 cm. The second loose segment is looped around another neighbouring plant making an angle of 30^{o}. The guys should be tightened to make sure they hold plant with the bunch being protected.

Guy Looped Around the Base of the Leaves of the Plant

Guys Are Anchored from Neighbouring Plants

Guys Must be Tightened for Greater Support

Guys are easy to procure, but need to be removed from the plantation to be re-used and to avoid soil contamination with old guys that could become a terrible problem.

The aerial cable is the best method to support a banana plant to avoid field losses. The cable is very well suited to the High-Density Double Row planting system but can also be used in existing plantations. In the Double Row system, the cable or wire is placed on a post in the middle of the double row at a height exceeding the height of the mother (matured) plants. The minimum height should be 5 m. Within the double row, the posts are spaced at 6 m. Since the next doble row is 5 m apart, the cable and posts form a 5 m x 6 m grid that allows to securely tie the plants to the wire and keep them from falling even in high wind situations. The wire should at least be 14 gauge or higher. When the aerial cable protects the bananas from elephant damage as well, the diameter of the cable must be enough to handle their loads.

The holes to anchor the posts in the aerial cable grid must be 1.5 ft deep and the posts should be tightly packed into the hole to remain erect and stand the weight loads. The packing should be done with small stones (coarse gravel), sand and soil.

A similar grid can be built for existing plantations.

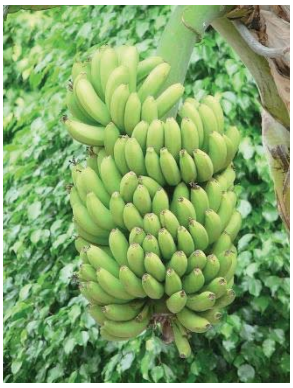
Aerial Cable to Prevent Filed Losses, Especially Under Strong Wind

12. QUALITY PRACTICES

12.1 Bunch Clearing

Once the flower bud bends towards the ground, it is necessary to clear all material such as the placenta leaf, other leaves, bracts, and other physical obstacles that can become in contact with the fruit bunch during its development causing damage. By clearing the bunch, much of the appearance quality is assured because the fruit will be free from blemishes. Very sharp bush knives and cutting tools on poles are used on a weekly basis for this purpose. At this point, the placenta leaf is pushed backwards as well.

The Bunch is Free from Contact with Objects that Can Cause Damage



Bunch Free from Mechanical Damage

High Quality Cleared Bunch

Bending Placenta Leaf Backward

Dry Leaves Touching Fruit Bunch

Bracts and Propping Pole Touching Fruit Bunch

12.2 Bagging

Bagging is also a weekly practice and consists of placing a plastic cover over the bunch to protect the fruit against mechanical and biological damage or against the application of chemical products. The cover creates a microclimate that maintains a high temperature and prevents chill damage. This microclimate can reduce by many days the flower-to-harvest interval (between 4 to 14 days depending on the type of cover and the environmental conditions) and increase bunch weight.

The cover (bag, tree bag, bunch cover) generally has a thickness between 12 to 25 microns and is made of polyethylene that is perforated every 76 mm. Each hole is 12.7mm in diameter. The cover is 90 cm in diameter and 155 cm long or more according to the size of the bunch.

There are two types of bagging: traditional or normal (the cover is placed at the last horizontal hand stage; at which time the bracts have fallen) and early bagging (when no hand is yet visible). This last practice is the preferred practice but requires removing the fallen bracts that get stuck inside the cover. If they are not removed in time, the advantages of early bagging are not realized. These advantages are a more accurate determination of fruit age and the prevention of insect damage. In fact, in locations where flower thrips are a problem, early bagging is recommended.

Used plastic bunch covers must be removed from the plantation and collected for recycling.

Early Bagging Physiological Stage

Bagging in High Density Double Row

Plastic Film with Ventilation Pattern for Banana Tree Bags or Bunch Covers

Bananas Inside Tree Bag

12.3 De-Flowering

The flowers at the tip of the small banana fingers must be removed as the fruit bunch develops to avoid mechanical damage to the fruit when they become old and hard and sharp as a thorn. This practice also reduces the amount of inoculum for diseases such as crown rot, crown Mold and neck rot and avoids undesirable waste at the packing shed. The removal of the flowers has to be done gradually by hand within a week as the hands become exposed and the flower petals begin to fall off. At this time, the banana hands are pointing downward and the flowers to be removed are very tender and come off easily. Special care needs to be taken to avoid latex burn. This is the main reason a fruit bunch being de-flowered is visited at least 3 times in a week. De-flowering is a delicate operation that needs to be done with a great deal of precision.

De-Flowering Practice

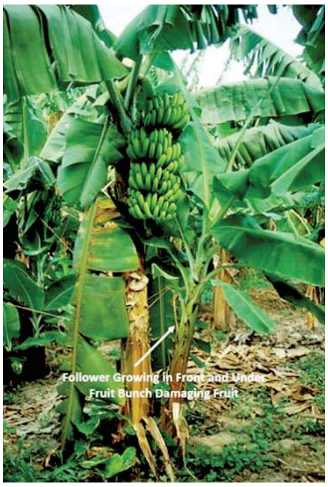
Upper Hands Ready for De-Flowering

Fruit Bunch with All Flowers Removed

Deflowering Practice at the Banana Pilot Project

12.4 Deviation of Followers

Sometimes the follower grows in front of the mother plant and underneath the fruit bunch. When this happens and as the follower grows, it will interfere with the bunch causing damage to the quality of the fruit from friction appearing as scratching and/or bruising damage. In addition, the fruit bunch affects the follower's growth as well. In these situations, is necessary to deviate the follower to avoid its collision with the fruit bunch. This is accomplished by forcing the follower away from the fruit bunch and securing it by tying it to the mother plant using dry banana tissue or a plastic twine. Dry banana tissue is, of course, a cheaper way to accomplish this task.



Follower Obstructing Fruit Bunch

Follower Already Affecting the Quality of the Fruit Bunch

Deviated Follower Tied to Mother Plant

Tying Follower to Mother Plant to Deviate

Follower Deviation Practice at Banana Pilot Project Farm

12.5 De-Budding and De-Handing

As the development of the banana bunch continues and the hands begin to bend upward, the remnants of the flower bud are removed by hand on a weekly basis as well as the false hands that are made up of both masculine and feminine fingers. The objective of this practice is to remove waste material to increase the energy available for the development of the remaining true fingers and hands. In addition, this practice removes obstacles that affect the harvest of the bunch and could diminish quality. When removing the bud and the false hands, it is very important to leave one or two fingers attached to the nearest false hand to the true hands in order to prevent the spread of bacterial rot. Sometimes, additional hands are removed together with the false hands. This practice accelerates the development of the remaining hands causing them to reach harvest grade faster. In addition, the practice is also used to increase the finger length of the lower hands according to market demands.

Banana Bud Ready for Removal

Removing the Bud by Breaking it off the Bunch

Removing the False Hand(s)

Bunch After Removal of False Hand(s)

13. TAGGING FOR AGE AND FRUIT INVENTORY

The age of the fruit, expressed in weeks from bagging, is a very important criterion for harvesting bananas to prevent premature ripening and guarantee young and healthy fruit is harvested, with a longer shelf life and maximizing farm productivity. Plastic coloured ribbons are used for tagging the fruit to determine its age. Every week, a different colour is used for tagging based on an annual colour chart (Coloured Ribbon Calendar) prepared by management. It is important to use the same chart for all farms shipping fruit together.

Week No.	W/E																
1	7-Jan																
2	14-Jan																
3	21-Jan																
4	28-Jan																
5	4-Feb																
6	11-Feb																
7	18-Feb																
8	25-Feb																
9	4-Mar																
10	11-Mar																
11	18-Mar																
12	25-Mar																
13	1-Apr																
14	8-Apr																
15	15-Apr																
16	22-Apr																

Figure 7: Coloured Ribbon Tagging Calendar

The ribbon is made of 40 to 80-micron thick plastic, 2 inches wide and 1 to 2 meters in length. Usually, 8 colours are used although some farms prefer to use 12 colours. The ribbons are placed together with the plastic tree bags in the same operation. At the beginning of the farm day, the ribbons corresponding to the colour of the week are counted and given to the bagging crews. At the end of the farm day, the crews bring back any ribbons they may have leftover. In this way, the supervisor generates the ribbon count for that day using the count given minus the count returned.

The Fruit Desk of the plantation or farm keeps the count of the number of ribbons placed in a week. These counts create a true inventory (fruit inventory) of banana bunches hanging by colour (age). This inventory is kept until all the fruit for the colour is harvested. Losses and sales to the local market of tagged fruit are also part of the fruit inventory. The Fruit Desk Officer keeps and manages the fruit inventory. Counts making up the inventory enable the plantation to know, with a high level of confidence, how much fruit is available 10 to 12 weeks in advance of the harvest. This knowledge is crucial for planning the shipping capacity required and the marketing and sales strategy for the fruit. The fruit inventory is also used to procure packing materials and supplies such as chemicals, boxes, plastic, and foam pads.

All plastic ribbons are collected and brought into the office to be counted and recorded by the Fruit Desk Officer as part of keeping the fruit inventory. Afterwards, they are recycled.

14. PEST AND DISEASE MANAGEMENT

IPM concepts and practices must be applied to manage banana pests and diseases. The Quantity/Intensity factor is a practical and easy to apply IMP concept in deciding whether to apply pesticides:

Quantity	**Coverage**
Intensity	**Severity**

	Quantity		
Intensity	**Low**	**Medium**	**High**
Low	Observation	Observation	Localized
Medium	Spot Treatment	Localized	Full Treatment
High	Localized Treatment	Full Treatment	Full Treatment

The most common banana pests and diseases found by ISP during implementation of the ASMP in Sri Lanka are:

14.1 Fusarium Wilt of Bananas (Panama Disease)

Fusarium wilt of banana, popularly known as Panama disease, is a lethal fungal disease caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *cubense* (*Foc*). It is the first disease of bananas to have spread globally in the first half of the 20th century. The epidemic started in Central America on the susceptible Gros Michel banana, which at the time dominated the global export trade. In the 1950s, 'Gros Michel' was replaced by Cavendish cultivars. At the end of the 1980s, the so-called TR4 strain, to which Cavendish cultivars are susceptible, was isolated from samples from Taiwan. It has since spread through Asia and reached Africa in 2013. It was reported in Mozambique and in 2019 in Colombia.

Tropical race 4 (TR4) is the name of the fungal strain that causes Fusarium wilt (aka Panama disease) in Cavendish cultivars and a wide range of other cultivars.

The fungus enters the plant through the roots and colonizes the xylem vessels thereby blocking the flow of water and nutrients. Disease progression results in the collapse of leaves at the petiole, the splitting of the pseudo stem base and eventually plant death. The fungus cannot be managed using chemical pesticides. The solution best adapted to the continued production of bananas in infested soils is replacing susceptible cultivars by resistant ones.

TR4 can be spread through infected planting material, infested soil, and water.

Like all other soil dwelling *Foc* strains, TR4 cannot be controlled using fungicides and cannot be eradicated from soil using fumigants. The capacity of TR4 to survive indefinitely in the soil, along with its lethal impact and wide host range, are among the main reasons it was ranked as the greatest threat to banana production. To avoid further losses to the pathogen, the United Nations Food and Agriculture Organization (FAO) has called on banana-producing countries to step up monitoring and reporting, and to contain suspected incursions to prevent the fungus from getting established.

The primary line of defence is the exclusion of all non-essential visitors, vehicles, and plant material from outside. This is part of a strategy to manage people and vehicle access that is called *differential access zoning*.

Some of the actual practices put in place at the farm include:

1. Vehicle wash-down facilities that use disinfectants such as Farm cleanse, Sporekill or Domestos.
2. Physical barriers.
3. Facilities for footwear change or disinfection at zone boundaries within the farm.
4. Mat to mat Disinfection of field cutting tools.
5. Managing the movement of water and soil.
6. Putting in place measures that reduce soil erosion, such as ground covers and grassed inter-rows, would also lessen the severity of Fusarium wilt.

These practices also provide a barrier to the entry of other pests, diseases, and weeds.

Protocol for Containment of Panama Disease at the Farm Level

1. Diseased plants must be removed or killed. The best way is to kill plants is *in situ* using a Round-up injection one foot from the base of the plant. For small followers, spray Round-up in the growing point. If Round-up is not available, remove plants with roots included, take them to a safe area and burn them. In the holes left after removing the plants, spread activated lime thoroughly.

Killing a Banana Plant Infected with Fusarium Wilt Using a Round-up Injection

2. People that have walked in the affected plot need to disinfect their shoes before going out or wear different shoes and clothing to go visit other farms.
3. Use a 5% Bleach solution as an all-purpose disinfectant (formaldehyde or a new product such as Farm cleanse is better).
4. The farmer and all visitors will need to disinfect their shoes entering and leaving the plantation. PPMU, ISP, DOA, etc. must also disinfect their shoes in and out.

Field Tool Disinfection Containers for Bananas to Prevent Panama Disease

5. Disinfect all cutting tools as well as they are used from plant to plant. That means, a special container, with disinfectant, is necessary inside the plantation to carry the tools.

PVC Containers to disinfect banana field tools to contain Panama Disease

Rotation Cropping

As mentioned above, there is no cure for the Fusarium Wilt of bananas. The High-Density Double Row system offers a rotation option within the same cultivated plot. In other words, there is no need to move the plantation to a new field. Simply, the double row is moved to the centre of the double row aisle when the infection rate reaches 25% to 30%. The farmer can continue to harvest the bananas from the affected double row until the new double row is bearing fruit. However, tissue Culture planting material must be used.

The centre of the aisle must be prepared to receive the new double row using a drenching of neem extract two weeks before planting. At planting time, Trichoderma fungi must be spread into the planting hole.

14.2 Black Leaf Streak (BLS) or Black Sigatoka Disease

(*Pseudocercospora figiensis)*

BLS is also known as Black Sigatoka disease of bananas and is caused by the fungus *Mycosphaerella fijiensis.* The disease effects only the leaves of the plant by creating small black streaks on the underside of the leaves that later on can become necrotic spots, which in turn could develop into full blown leaf necrosis, totally destroying the green photosynthetic tissue. All leaves of the plant could become infected during severe outbreaks, blocking photosynthesis completely. Yield potential is, therefore, severely curtailed. In addition, Black Sigatoka infection enhances enzymatic activity that accelerates the ripening of the bunch of bananas. Ripening also is increased when the banana plant has a small number of photosynthetically active leaves at harvest. In both cases, the banana bunches must be harvested prematurely before full development, a condition that causes severe reductions in bunch weight and yield. This collateral damage from BLS persists throughout the supply chain, including shipping and distribution.

This disease profile demands very effective preventive and control measures using both GAP and IPM concepts and principles. Measures of this type take advantage of the fact that Black Sigatoka is a seasonal disease, severe in the rainy season and light in the dry season. However, prevention begins with the proper application of field cultural practices all year around since they have a positive effect on plant vigour and health, physiological conditions that prevent or minimise the effects of the fungus. Furthermore, the disease thrives in wet and humid conditions. Thus, practices such as irrigation and drainage become crucial in the overall strategy against Black Sigatoka. Even small puddles of water, from rainfall or excess irrigation, can become triggers of the disease. Therefore, good surface drainage, as a counter measure to offset these conditions, is one of the main tools to prevent severe infections, together with the proper application of water through irrigation.

The removal of infected material is also crucial to prevent the spread of the disease. Affected leaves and/or affected leaf portions must be quickly removed to reduce the inoculum load. To achieve this objective, de-leafing and leaf surgery practices must be implemented dutifully on a weekly basis. Leaf surgery is the selective cutting out of infected leaf portions, preserving the uninfected green tissue to maximize the photosynthetically active leaf area throughout the whole plant under disease conditions. Every little portion of green tissue matters. As a bonus, the removed biomass should remain in the plantation as a source of organic matter and mulch. Spores from the fungus die quickly in necrotic tissue and do not participate in spreading the disease; thus, discarded biomass carries no disease risk.

Without preventive measures, the use of chemicals is a waste of money. However, chemicals must be used when the youngest leaves become infected. The IPM way to determine the right timing for chemical application is through a weekly leaf survey. For this purpose, 5 recently shot plants per acre are selected to determine the presence of streaks on the youngest leaves. This survey is known as the Youngest Leaf Spotted (YLS) survey. The IPM threshold to trigger a fungicide application is black streaks on leaf number 7.

There are two types of fungicides used for Black Sigatoka control, systemic and contact. Systemics have restrictions in their frequency of application because of the development of resistance by the fungus. Therefore, continuous applications are not permitted and the number of cycles of systemics per year are also limited to between 2 and 4, depending on the fungicide. In any event, the maximum number of cycles of applications of chemicals allowed under GAP is 24 per year.

The frequency of applications (cycles) can vary according to the severity of the disease as determined by the YLS survey. During high infection season, the cycles can be shortened to even one per week if the infection is apparent in the very young leaves. As the infection pressure decreases and the youngest leaves become clean, the cycles can be lengthened. In the dry season, cycles can even be made six weeks apart or more or even completely suppressed. Contact fungicides can be used in conjunction with or in between systemics applications to meet the requirements of the restrictions on the use of systemics. Hence, the use of chemicals in Black Sigatoka control must be flexible, dynamic, and balanced, depending on the climatic conditions affecting the YLS, the type of fungicide, the restrictions for systemics and the field cultural practices. This is IPM at its best.

The mixing requirements vary according to the fungicide applied. Most systemics demand high speed mixing to prepare a stable spray mix. Contact fungicides are more flexible and sometimes are applied in combination with oil or water. The instructions on the label must be read carefully and applied accordingly. Adjuvants (stickers) are indicated to be used in times of heavy rainfall but must be compatible with the fungicide. In addition, all applications must be made using a calibrated mist blower and the use of full protection clothing is mandatory.

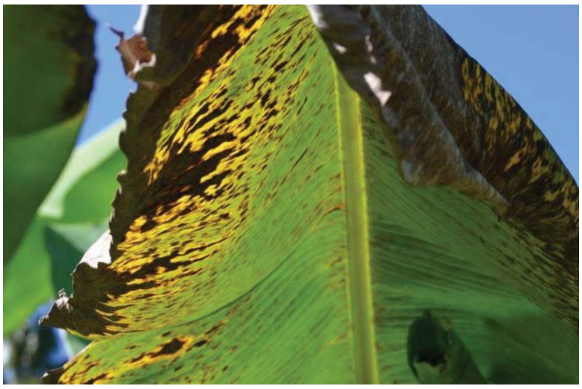
The most commonly used fungicides in Sri Lanka for Black Sigatoka control are:

Contact Fungicides		Systemic Fungicides	
Commercial Name	**Active Ingredient**	**Commercial Name**	**Active Ingredient**
Manzate	Mancozeb	Miltek C	Triadimefon Carbendazim
Bravo	Chlorothalonil	Punch	Flusilazole
		Luna Privilege	Fluopyram
		Tilt	Propiconazole

The recommended amounts of product or active ingredient contained in the label must be followed for all fungicides.

Infection on Lower Leaves

Streaks and Tissue Burning



Young Plants Affected by Black Sigatoka *Close up of the Disease on the Tip of the Leaf*

Severe Stage of BLS Affecting the Fruit Bunch (All Leaves Burned)

14.3 Banana Bunchy Top Virus (BBTV)

BBTV is the most devastating disease for bananas in Sri Lanka. It is transmitted mechanically through infected planting material and plantation tools. The major insect vector is the aphid *Pentalonia nigronervosa,* that often acts in symbiotic association with ants. A single aphid is capable of disease transmission; therefore, transmission is not related to the population dynamics of the vector.

Aphids on Banana Leaf Petioles

Aphids Infestation on Banana Lower Leaves

The most common symptoms are bunching and curling of the leaves, together with leaf vein chlorosis and yellowing of the leaf margins. The leaves grow smaller and tend to develop erect and narrow. The symptoms are more common observed on smaller plants, especially small suckers. In taller plants, mainly the younger leaves are affected.

The spread of BBTV can be prevented by using common Good Agricultural Practices (GAP) such as restrictions in the movement of infected planting material between and within countries, restricted use of tools between plantations and the control of ants and aphids. The ants protect the aphids because they have a symbiotic relationship. The ants feed the honeydew excreted by the aphids. This is a mutual beneficial relationship for both species.

Sanitation of the plantation is extremely important to deny a haven for both ants and aphids. All dry matter must be removed from the plant, avoiding hanging or clinging appendages or "ears" (portion of petioles left behind after leaf removal). Dry as well as bent and hanging leaves, in addition to the dry layers of the pseudo-stem, must be removed. However, the most important preventive measure is the use of clean planting material, generated and multiplied by tissue culture techniques. Sri Lanka has adopted this technology in the new plantations being developed for export.

In addition to the GAP described above, Integrated Pest Management (IPM) practices are used to prevent the spread of BBTV. If BBTV is present at an economically significant level within a plantation (5 or more cases per acre), the populations of aphids and ants must be assessed to determine the risk of spreading the disease. Ants are of more concern in the survey. A random sample of 13 plants per Acre within the survey area selected for populations counts for both aphids and ants. Plants with 50 or more active ant individuals are considered towards the threshold which is considered breached if 20% of the plants surveyed meet the criteria.

Aphids and ants should be controlled chemically if population threshold is exceeded. However, blanket applications of insecticides must be avoided at all costs to protect beneficial insects such as lady beetles. Common ant control chemical measures include spraying with S-methoprene, Hydramethylnon and the use of traps, preferably made with repellents that can be used around the pseudo-stem. Aphids are easily taken care of by applying natural oils, such as neem or mineral oils and soapy water, directly on the aphids.

Diseased plants must be removed from the plantation as quickly as cases are discovered and the resulting hole after removal must be treated (covered liberally) with coral lime or urea and left for 2 weeks before replanting. The eradicated material must be destroyed either by burning or burial.

Banana Bunchy Top Virus Symptoms

14.4 Cigar End Rot (Black Tip Rot)

Cigar end rot is an important disease of banana, which is caused by the fungus *Verticillium theobromae.* The disease is prevalent in almost all banana growing tracts and affects the developing fingers. It causes a dry rot of the flower end that produces an ash grey wrinkled lesion on the banana fingers, like the burnt end of a cigar.

Climatic conditions favouring Cigar End Rot:

- Severe temperature
- Drought Conditions
- Dry and wet climatic environment caused by pulses of rainfall.
- Over and under watering with irrigation
- Changing relative humidity
- Poor drainage or standing water inside the plantation during very hot days.

Avoid "ears" from mat sanitation.

Prevention of Disease

- Disease can appear on the stem of the bunch (raquis) and on the crowns and fingers of the banana hands.
- Field sanitation, such as the removal of dead, hanging leaves from plants, reduces inoculum level. Avoid "ears" after sanitation.
- Avoid damage to the fruit and deflower as quickly as possible.
- De-flowering is critical because the fungus comes in through dried banana flowers or little wounds made by improper de-flowering.
- Remove the untransformed flowers after the finger emergence.
- Bagging of banana stems: Make sure plastic bags meet specifications to create proper ventilation to avoid a harmful micro-environment inside the bag.

Make sure plastic bags to cover the bunch meet specifications to create proper ventilation and avoid a harmful micro-environment inside the bag.

The cover is generally made of 0.08 mm thick polyethylene that is perforated every 76 mm. Each hole is 12.7mm in diameter. The cover is 90 cm in wide and 155 cm long. The length of the bag can be adjusted to the length of the bunch in the area of interest. The bag thickness is generally between 12 and 25 µm.

Chemical Treatment

- Exhaust preventive measures before chemical treatment
- Use contact fungicides before systemic ones.
- Mancozeb, a broad-spectrum contact fungicide, is commonly used.

- Follow the label recommendations.
- Spraying is difficult because of the plastic bunch bag.

14.5 Banana Flower Thrips

Thrips (*Thrips hawaiiensis*) are small, slender-bodied active insects, readily seen moving on the surface of young banana fruit, particularly near the 'bell' or male end of the new bunch. Adult females (1mm) are distinctly coloured – bright orange and black – and are usually found under bracts or inside flowers.

Males (0.75mm) are pale straw-coloured and are usually found on the outer surface of the bracts. Adult thrips have characteristic wings; the transparent wings have a fringe of hairs around the outside edge standing out in the same plane as the wing. They are easily seen with a x10 hand lens.

The immature stages are wingless, smaller than adults and are pale, almost transparent.

Thrips have a wide host range.

Life Cycle

The life cycle, which is completed on the bunch, takes about 3 weeks. Eggs are laid just below the surface on young fruit and on the bunch stalk. Two active nymphal stages are followed by 2 or 3 pupal stages before the adult stage. Thrips are found throughout all banana-growing areas.

Damage

Thrips cause corky scab, which is primarily a problem in the drier banana-growing areas. They are active throughout the year. The period of greatest activity is after the wet season.

Flower thrips damage to a young fruit - Photo IT2

Flower thrips damage at harvest - Photo UGPBAN

Fruit damage is caused by feeding and oviposition. Feeding damage results in slightly raised areas on the fruit that are grey, brown to grey silver at first (sandpapery feeling). They develop to form the corky raised areas of brown corky scab. Damage is confined in most cases to the outer curve of the fruit, particularly near the cushion end where the fruit finger joins the bunch stalk.

In severe infestations, damage can spread to other areas of the fruit. Bottom hands (closest to the male flower) are most at risk, but in severe cases, damage can extend to cover most of the bunch.

Oviposition on young fruit produces minute raised spots with a dark central tip on the fruit surface. This damage has little economic importance since it becomes almost unnoticeable as the fruit develops and matures.

Control

No direct relationship between thrips numbers and subsequent damage is evident indicating that other factors, apart from pest numbers, are important in determining fruit damage. A range of predatory bugs, ladybird beetles and lacewings assist in reducing thrips populations.

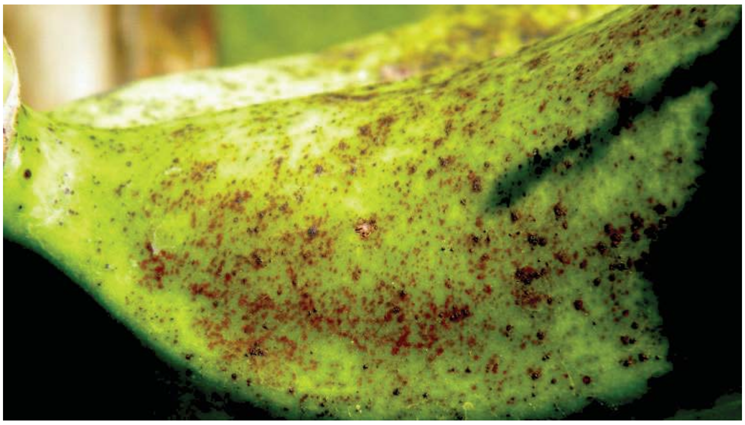
Early bagging after the emergence of the flower and before it bends downward and the removal of the male 'bell' where adult thrips move after all hands are exposed, may help in reducing thrips populations. This approach has not been evaluated. Evidence from observations and growers' reports suggest that overhead irrigation prevents corky scab in most situations.

14.6 Banana Freckle Disease

The banana freckle is caused by the fungus *Phyllosticta cavendishii*. There are other species of *Phyllosticta* that cause banana freckle, for example *Phyllosticta musarum and Phyllosticta musarum*has.

Symptoms

- Pinpoint like spots predominantly on leaves and fruit. On the fruit, spots are like the flower thrip damage.
- Spots can be very small to large (1–4mm) and dark brown to black in colour.
- The spots can run together to form streaks.
- Sometimes the centre of the larger spots is lighter in colour.
- Spots can also appear on the midrib of the leaf, bunch stalks and flower bracts.
- Severe infection results in yellowing of the leaf, which can wither and die.



Banana freckles can affect a banana plant at all stages of the production cycle. It mainly affects leaves and fruit.

Banana freckle is known to occur in parts of Asia including Bangladesh, Bhutan, China, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, and Vietnam. The disease is also present in Fiji, Hawaii, New Zealand, Papua New Guinea, Samoa, Solomon Islands and Tonga.

Life cycle

The freckle spots contain fungal fruiting bodies (perithecia and pycnidia). When it rains, following heavy dew or in poorly drained plantations, fungal spores such as ascospores and conidia are released. Conidia in particular play an important part in the infection cycle. They can be spread by raindrops or water splash onto or across leaves and fruit. The spores germinate, penetrating the host and multiply within and between cells, creating new spots in the superficial layers of the host plant tissue.

The incubation period can be as little as 20 days in hot humid weather.

Banana freckle is a 'wet spore' organism. It generally moves short distances by water droplet splash and wind driven rain. The fungus is spread over larger distances by people moving infected fruit, leaves and suckers used for planting.

Prevention and Control

Proper drainage, both for keeping the water table low and for quickly evacuating excess rainfall or standing water (surface drainage), is the most effective way to prevent Banana Freckles. The relative humidity of the plantation must be always kept as low as possible.

Fungicides such as Mancozeb are used sporadically to treat the disease in cases when the disease gets out of control.

14.7 Erwinia Soft Rot

Bacterial heart rot or Erwinia soft rot of banana is caused by Erwinia species. Erwinia carotovora ssp. carotovora (now renamed Pectobacterium carotovorum subsp. carotovorum), possibly in association with Erwinia crysanthemi.

Symptoms

- This disease is more pronounced on young suckers leading to rotting and emitting of foul odor.
- Rotting of crown region is a characteristic symptom followed by epinasty of leaves, which dry out suddenly.
- If affected plants are pulled out it comes out from the crown region leaving the corm with their roots in the soil.
- Splitting of pseudostem is common in late stage of infection in cultivars Robusta, Grand Naine and Thella Chakkerakeli.
- When affected plants are cut open at collar region yellowish to reddish ooze is seen.
- This soft rotting may spread radially towards growing point through the cortical tissues. The rotten corm emits foul smell.
- The disease can be spread by infected plant debris, plant wounds and injuries.
- Hot and damp weather with plenty of rainfall trigger the disease to occur. Water is required for the bacteria to invade into the plant.

Management

Good drainage and soil conditioning can control the disease to some extent.

- Plant disease free suckers.
- Remove infected plants immediately.
- Remove plant residues after harvest.
- Avoid flood irrigation especially using basins that hold water for some time.
- Proper drainage, both for keeping the water table low and for quickly evacuating excess rainfall or standing water (surface drainage), is the most effective way to prevent Erwinia Soft Rot of bananas.

14.8 Banana Stem Borer Weevil

The Banana Stem Borer Weevil (*Cosmopolites sordidus*) is a destructive pest that affects banana plants, primarily targeting the rhizome and pseudostem.

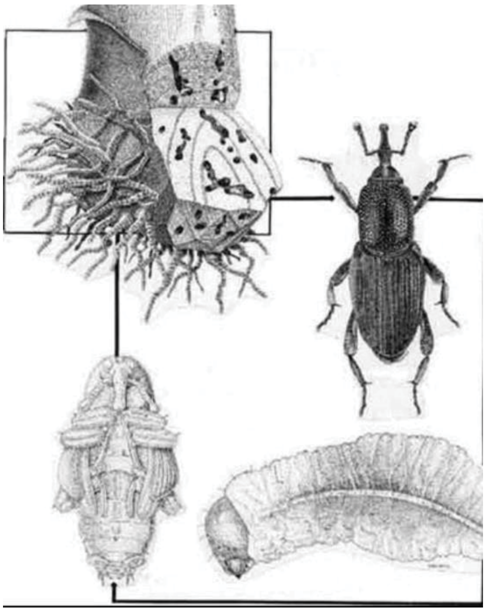
Characteristics:

The Banana Stem Borer Weevil is a small insect belonging to the family Curculionidae. It is approximately 5 to 15 millimeters in length and has a dark brown or black coloration. The adult weevils have a characteristic elongated snout or rostrum, which they use to feed on and damage banana plants. The larvae of the Banana Stem Borer Weevil are legless, white, and have a curved body shape.

Life Cycle:

The life cycle of the Banana Stem Borer Weevil consists of four stages: egg, larva, pupa, and adult. Adult weevils lay eggs on the surface of the banana plant, usually near the base of the pseudo stem or in cracks and wounds. The eggs hatch into larvae, which bore into the rhizome or pseudo stem and feed on the inner tissues. The larval stage lasts for several weeks, causing extensive damage to the plant. Upon completing their development, the larvae pupate within the infested plant material. Adult weevils emerge from the pupae and repeat the life cycle.

Damage Caused:



The Banana Stem Borer Weevil causes significant damage to banana plants, affecting their growth, productivity, and overall health. The larvae bore into the rhizome and pseudostem, creating tunnels and feeding on the plant's vascular tissues. This disrupts the transport of water and nutrients, resulting in wilting, stunting, and reduced yield of the bananas. Infested plants may exhibit symptoms such as yellowing, premature ripening, and an overall decline in vigor. Severe infestations can lead to plant death.

Management Strategies:

Effective management of the Banana Stem Borer Weevil requires a combination of cultural, biological, and chemical control methods. Here are some common strategies:

1. Cultural practices: Implementing good agricultural practices such as removing and destroying infested plant material, practicing crop rotation, and maintaining proper sanitation in the plantation can help reduce the pest population.

2. Biological control: Introducing natural enemies of the Banana Stem Borer Weevil, such as parasitic wasps, nematodes, or predatory beetles, can provide biological control. These beneficial organisms help control the weevil population and reduce its impact on banana plants.

3. Chemical control: In severe infestations when other control measures fail, chemical control may be necessary. Insecticides specifically targeted for weevil control can be applied to the affected areas following recommended guidelines and considering safety precautions. It is important to follow the recommended dosage and application instructions provided by manufacturers to ensure effective control while minimizing negative impacts on the environment, humans, and beneficial organisms.

Chemical control should be used judiciously and as part of an integrated pest management approach, combining it with cultural practices and biological control methods for long-term sustainable management of the Banana Stem Borer Weevil. Regular monitoring and careful evaluation of the efficacy and impact of chemical control measures are crucial to ensure their effectiveness and minimize any potential risks.

Several chemicals can be used to control the Banana Stem Borer Weevil (Cosmopolites sordidus) in banana plantations. These chemicals are specifically formulated to target and eliminate weevils. Common insecticides used for Banana Stem Borer Weevil control include synthetic pyrethroids, organophosphates, and carbamates. Examples of active ingredients in these insecticides may include bifenthrin, chlorpyrifos, cypermethrin, and carbaryl. These chemicals work by interfering with the nervous system of the weevils, leading to their paralysis or death.

It is important to strictly adhere to the recommended dosage, application method, and safety precautions specified by the manufacturer when using these insecticides. Additionally, it is advisable to rotate different chemical classes and adopt an integrated pest management approach to prevent the development of resistance in the weevil population and minimize any potential negative impacts on the environment and non-target organisms.

4. Integrated Pest Management (IPM): Implementing an integrated approach that combines various control methods, such as cultural practices, biological control, and targeted insecticide use, can enhance long-term management of the Banana Stem Borer Weevil.

14.9 Red Rust Thrips

Red Rust Thrips (Chaetanaphothrips signipennis) is a significant pest affecting banana crops worldwide. Damage to the fruit is common under high infestations. The attack by thrips can occur at any growth stage and is visible on leaves, pseudostems, and fruits. These thrips are tiny insects, and it is difficult to identify them with the naked eye due to their small size (about 1-2 mm). They are yellowish-brown in color and have fringed wings.

Adults and larvae usually settle behind the bases of leaf sheaths. Nymphs are gregarious and feed by sucking the plant sap with their mouthparts. Initial symptoms appear as water-soaked areas on fruits. Over time, these areas give the fruits a characteristic rusty aspect, with deep red to dark brown colored skin. Usually, only the peel shows damage, but if infestation is heavy, the whole fruit can show signs of damage. On more mature fruits, cracks may be visible. Sometimes the fruits split open.

Biology and Life Cycle:

Red Rust Thrips undergo four developmental stages: egg, larva, pupa, and adult. They thrive in warm and humid conditions, making banana plantations particularly susceptible to infestation. The thrips feed by puncturing plant cells and extracting sap, resulting in characteristic silvering or bronzing of leaves.

Damage Symptoms:

1. Silvering or bronzing of leaves.
2. Reduced plant vigor and growth.
3. Premature leaf senescence.
4. Severe damage to fruits causing low quality and poor marketable yields.

Control Strategies:

1. Cultural Practices:
    - Regular pruning and removal of infested plant material.
    - Maintenance of proper spacing between banana plants to reduce humidity and create less favorable conditions for thrips.
2. Biological Control:
    - Introduction of natural predators, such as predatory mites or parasitoid wasps, to control thrips populations.
    - Use of beneficial nematodes that attack thrips larvae in the soil.
    - Organic control measures include using parasitic insect species from the chrysopidae family and ladybug beetle species to control the pest. Some ant species might be effective too. They attack the pupae in the soil.
3. Chemical Control: Chemical control measures include an integrated approach with preventive measures together with biological treatments. If insecticides are needed, applications should be located on the soil to kill the pupae, as well as on plants and fruits in order to kill the adults. This approach might be the only possibility to avoid re-infestation.
    - Application of insecticides is a common method to control Red Rust Thrips. However, it is essential to use these chemicals judiciously to minimize environmental impact.
    - Selective insecticides such as neonicotinoids or insect growth regulators can be effective against thrips while minimizing harm to non-target organisms.
    - Specific Chemicals for Control:
        a. Neonicotinoids:
            I. Imidacloprid
            II. Clothianidin
            III. Thiamethoxam
        b. Insect Growth Regulators:
            I. Pyriproxyfen
            II. Methoxyfenozide
        c. Botanical Insecticides:
            I. Neem oil (Azadirachtin)
            II. Pyrethrins
        d. Organophosphates:
            I. Malathion
            II. Chlorpyrifos

Red Rust Thrips pose a significant threat to banana crops, and their effective management requires an integrated approach. Cultural practices, biological control, and careful use of chemical measures can contribute to sustainable pest control while minimizing environmental impact. Regular monitoring and adaptation of control strategies based on local conditions are essential for successful management of Red Rust Thrips in banana plantations.

Banana Bud Injection

Banana bud injection is a technique used to protect the banana fruits from Red Rust thrips. The process involves injecting a registered insecticide into the flower bud upper one third portion when the bud is about 50% to 75% out, using a special device called a banana bud injector pump. The insecticide should fully drench the bud and remain inside for about 5 seconds to ensure even distribution[3]. The injection should be done at the right stage and volume to avoid chemical damage to the bud or fruits. Bud injection can help reduce thrips population and improve the quality and yield of banana fruits.

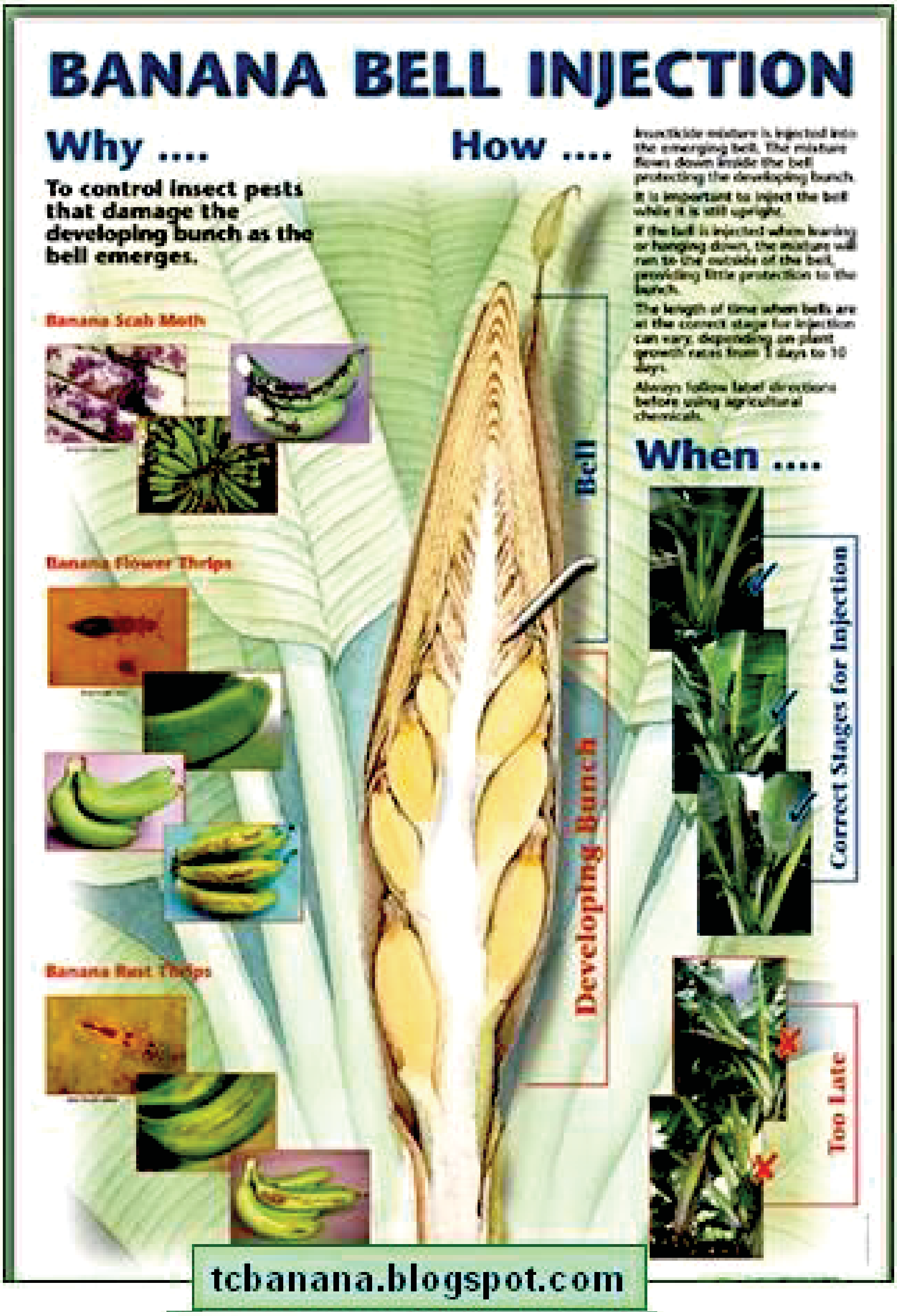


Figure 8: Bell Injection Spear

14.10 Intercropping

The double row and high-density planting system is very well suited for intercrops with bananas in the 4 m alley between double rows.

Intercropping is allowed until the coverage of the banana leaf canopy affects the growth and development of the intercrop by shading. Nevertheless, shade tolerant crops can be done at that time.

Intercrops of annual crops, such as onions or chili, could be used for better utilization of land and as a source of income for the farmers before the commercial production of the banana fruit begins in earnest.

Intercropping with crops that share common pests and diseases must be avoided. The use of chemicals that can harm the banana plant and the fruit must be avoided as well in intercropping.

(Reference is made to other ASMP Technical Operational Manuals made for short term crops that can be used as intercrops such as chili, onions, brinjal and okra).

15. BANANA HARVESTING

15.1 Harvesting by Age and Calliper Grade

1. Commercial bananas for export are harvested by age and calliper grade. A combination of fruit bunch ages at a fixed harvest calliper is used.
2. Age is determined by tagging the fruit bunch with coloured ribbons following an annual calendar. Different coloured ribbons signify different ages. Age is also used to some degree to manage fruit volumes.

3. The calliper of the fruit is used to maximize fruit export quality and field productivity and to manage fruit volumes. The optimum harvest calliper is determined using calliper surveys by coloured ribbon and by shelf-life observations to make sure the fruit remains "hard green" from farm to the international market.
4. A given coloured ribbon is to be harvested for 3 consecutive weeks beginning at age 10 and ending at age 12 for the small varieties such as Ambul and age 11 to 13 for Cavendish. The first two weeks, ages 10 and 11 (11 and 12 for Cavendish), the fruit is calipered using an optimum harvest calliper. The result is better quality due to size. The farmers productivity from a heavier bunch will be greater as well, and they will earn more money for a heavier bunch. In the third harvest week, all the bunches left for the given colour are harvested. This week is called the "sweep week". This protocol lowers the risk of fruit ripening during the voyage to the international market.
5. In each harvest week, 3 different coloured ribbons are harvested. For small bananas, the colour for age 10, the colour for age 11 and the colour for age 12 have to be harvested together according to the annual harvesting calendar which is based on the annual colour tagging calendar. For Cavendish, the colours for ages 11, 12 and 13 weeks are harvested together every week as well.
6. Since there are only 8 colours in a ribbon set, there will be very young fruit bunches also tagged with the same colour. These bunches must not be harvested. Only the "old" colour bunches are to be taken.
7. According to preliminary results from calliper surveys conducted in the field by the ISP Team in Anuradhapura, the optimum harvest calliper seems to be 30 mm for the small bananas varieties. For Cavendish, the harvest caliper is 36 mm.
8. A harvesting instruction is given every week before the harvest. The instruction specifies the colours to be calipered and the colour to be swept. The harvest calliper is also included in the harvesting instruction. Usually, 30 mm is the harvest calliper that must be used in the field with a graduated calliper tool.

The following chart summarizes the harvesting of small banana varieties and the Cavendish variety:

Variety	Harvest Ages	Calliper Grade
Small Bananas	10, 11 and 12	30 mm
Cavendish	11, 12 and 13	36 mm

15.2 Number of leaves at Harvest

The number of leaves at harvest is an important factor that can affect the quality of the bananas. Ideally, the mother plant should have 6 to 7 leaves at harvest to prevent ripening during the voyage to the international market and ensure the fruit is hard green on arrival before it is ripened in a special; room under a ripening protocol.

The number of leaves at harvest is affected mostly by Black Sigatoka disease that can literally burn the leaves. The youngest leaf spotted (YLS) by Sigatoka must be maintained at least at seven or more. The fungus causing this disease also has a toxin that enhances the ripening of bananas. Leaves can be lost and be lacking at harvest time because of extreme growing conditions such as drought or waterlogging. The farmer can also affect the number of leaves at harvest by over de-leafing before harvesting.

15.3 Harvesting Procedure

1. Harvesting will be done using the "fish line" de-handing at the mat technology applied to a plant placed in the "Number 7" position.
2. As the bunch is de-handed with the "fish line", the fruit is placed carefully on leaves taken from the harvested plant to allow for the fruit latex to flow out and for the crown to become free of latex as it becomes dry. This is the "de-latexing" technology to be used making sure the fruit crowns do not become in contact with the surface of the leaves and are simply "hanging" freely from the main vein of the leaf. If contact is made between the crown and the leaf, the crown will darken from the latex. This blemish needs to be avoided.
3. One plastic harvest crate will be used to place one entire bunch to be transported to the packing and/or processing facility (one crate per bunch method). The hands must be placed in the crate using a packing pattern determined in advance by the ISP Team to avoid mechanical damage and other damage from the field to the packing and/or processing facility.
4. The coloured ribbon for that bunch must be tied securely to the plastic harvest crate.
5. All ribbons must be collected and counted by colour at the packing and/or processing facility. This count must be reported promptly to the Fruit Desk for them to adjust the fruit inventory by coloured ribbon for the next harvest week and determine the recovery factor by coloured ribbon.
6. The harvest crate must be labelled by the farmer with his name as well before the harvest.
7. The "one crate per bunch method" and the "name label" will allow the packing and/or processing facility to determine the number of bunches harvested and delivered per farmer and the weight of the delivered fruit for accounting and payment purposes.



15.4 Harvesting Schedule and Production Forecast

The banana business for export is a weekly business. The banana week always begins on Sunday and ends on Saturday (W/E). The weeks are numbered according to the ISO week numbering system.

To facilitate the harvest, a harvest colour chart, based on the tagging colour chart, is prepared annually:

Week No.	W/E
12	25-Mar
13	1-Apr
14	8-Apr
15	15-Apr
16	22-Apr
17	29-Apr
18	6-May
19	13-May
20	20-May
21	27-May
22	3-Jun
23	10-Jun
24	17-Jun
25	24-Jun
26	1-Jul
27	8-Jul
28	15-Jul
29	22-Jul

Table 3: Tagging Color Chart

Every week on Saturday (week ending), a harvest program is made for the following week and a production forecast or estimate is created for the next 10 weeks. The table below contains a harvest program for Week 11 and a production forecast for the next 10 future weeks (Week 11 to 20):

Table 4: Harvest program and production forecast

				Harvest Week									
				3/20/2021	3/27/2021	4/3/2021	4/10/2021	4/17/2021	4/24/2021	5/1/2021	5/8/2021	5/15/2021	5/22/2021
Tag Week	Color	Count	Recovery	11	12	13	14	15	16	17	18	19	20
2		1,071	85	228	455	228							
3		1,713	85		364	728	364						
4		1,734	85			368	737	368					
5		1,829	85				389	777	389				
6		1812	85					385	770	385			
7		1850	85						393	786	393		
8		1822	85							387	774	387	
9		1703	85								362	724	362
10		1603	85									341	681
11		1885	85										401

This table contains all the major parameters required to manage the fruit such as the week the ribbon was put on the bunch (Tag Week), the colour of the ribbon, the count of bunches that were tagged with that ribbon colour (inventory), a recovery factor that accounts for bunches lost during the fruit development period and the bunches to be harvested at ages 10, 11 and 12 weeks (first and second calibration and sweep). It is necessary to remember that a particular colour is harvested for 3 consecutive weeks and that a complete harvest week is made up of three different ribbon colours.

15.5 New Tools Introduced

Telescopic Ladders

De-suckering Knife

Disinfection Containers

PVC Containers to disinfect banana field tools to contain Panama Disease

Harvesting Fish Line

16. POST-HARVEST HANDLING, PACKING AND SHIPPING

16.1 Bananas Postharvest Facts

- Bananas are climacteric fruits, which means they continue to ripen after harvest.
- The optimal temperature for storing bananas is between 13°C and 15°C (55°F and 59°F). Ambul bananas can be stored at 10°C (50°F).
- Bananas are sensitive to chilling injury, which can occur when they are stored at temperatures below 12°C (53.6°F), except for Ambul bananas.
- The ideal relative humidity for storing bananas is between 85% and 95%.
- Bananas produce ethylene gas, which can cause them to ripen more quickly. Therefore, it's best to store bananas separately from other fruits and vegetables.

16.2 Bananas Product Specifications

The product specifications for bananas to for export are as follow:

- Export Containers - Corrugated cardboard boxes containing 12 Kg to13 Kg net of fruit on arrival.
- Shipping fruit weight - 12.5 Kg to 13.5 Kg.
- Maturity Stage - Hard green.
- Tolerance – 5% to 10% by weight (1 hand per box).
- Sanitary and Phytosanitary Condition – Fresh and free from blemishes, diseases, and pests.

Calliper grade (girth or thickness):

	Minimum Calliper			Maximum Calliper		
Banana	**mm**	**Dole**	**International**	**mm**	**Dole**	**International**
Ambul	30	38	6	35	44	12
Cavendish	33	42	10	38	48	16

Dole (inches) = 1/32, International (inches) = 1/32 - 32

Finger length:

	Finger Length	
Banana	**cm**	**Inches**
Ambul	12	5
Cavendish	18	7

16.3 Transport from the Field to the Packing Facility

A 20-Kg plastic crate is used to transport the banana hands for packing. The crate must be lined on all sides with 3 mm Styrofoam cloth.

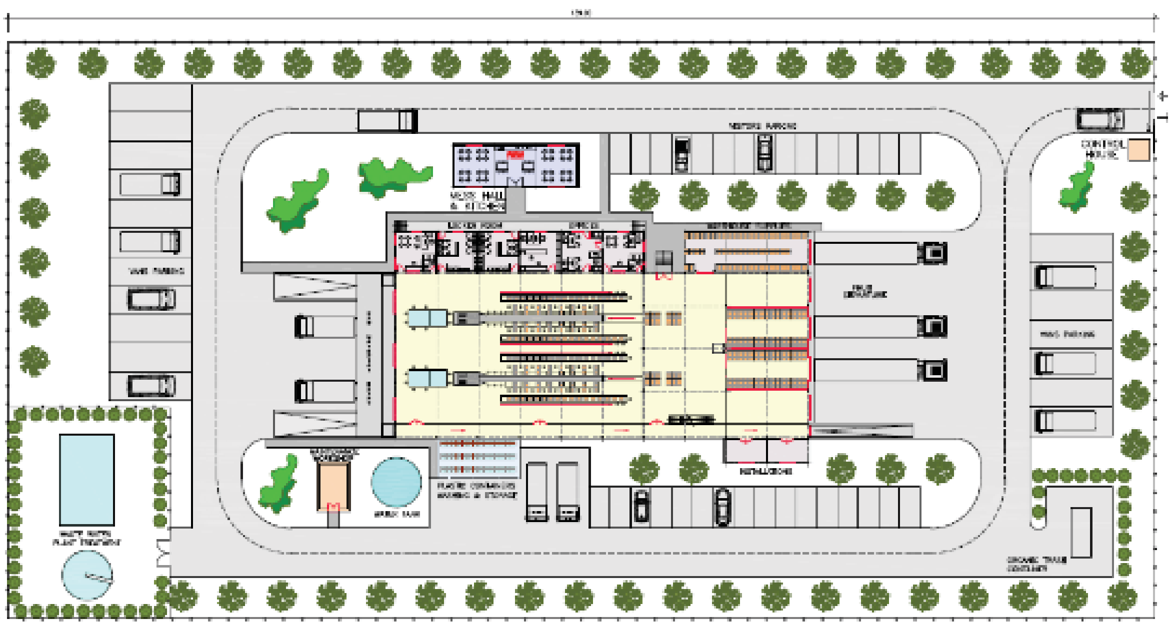
A flatbed trailer is often used as well. A foam mattress, 3 to 5 inches thick, is used to protect the banana hands during the trip. The hands are placed on the foam with enough separation and well distributed to avoid friction damage.

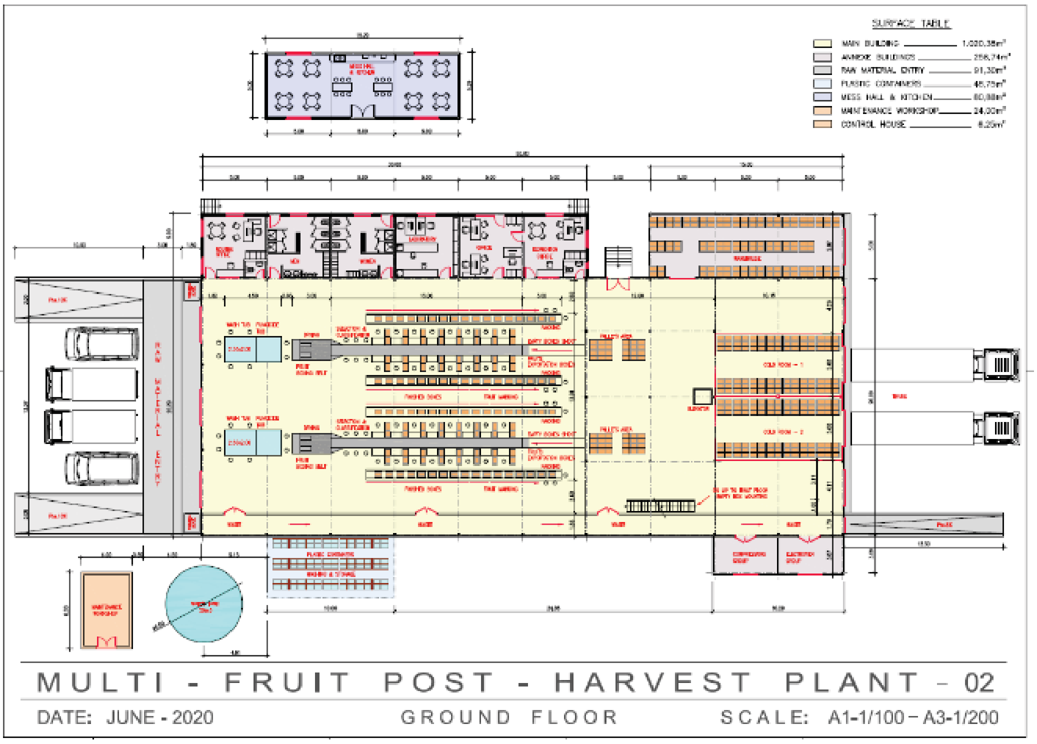
There are many other ways to bring the bananas from the field for packing as illustrated below.





16.4 Packing Centre Layout



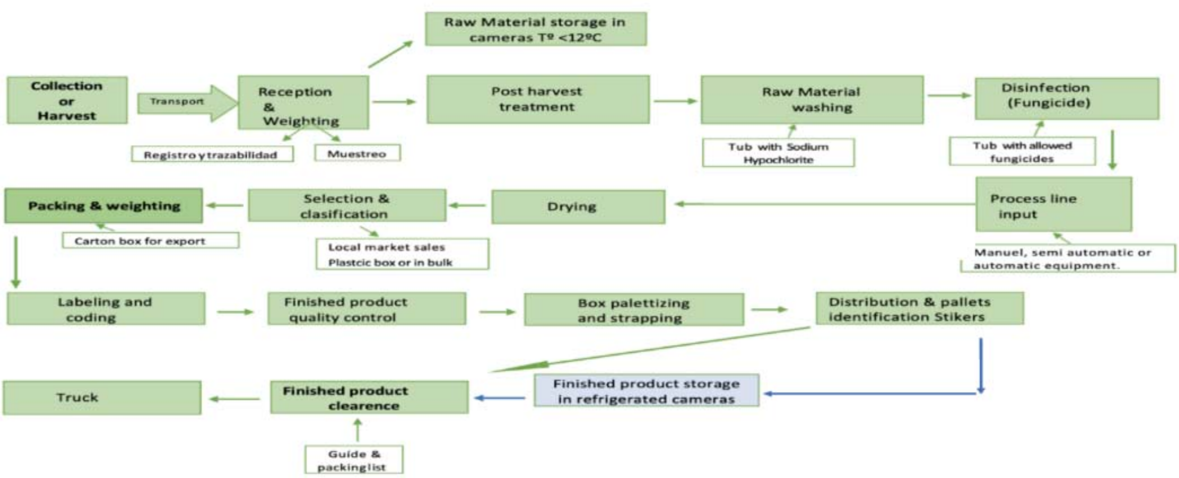


16.5 Post-Harvest Processes

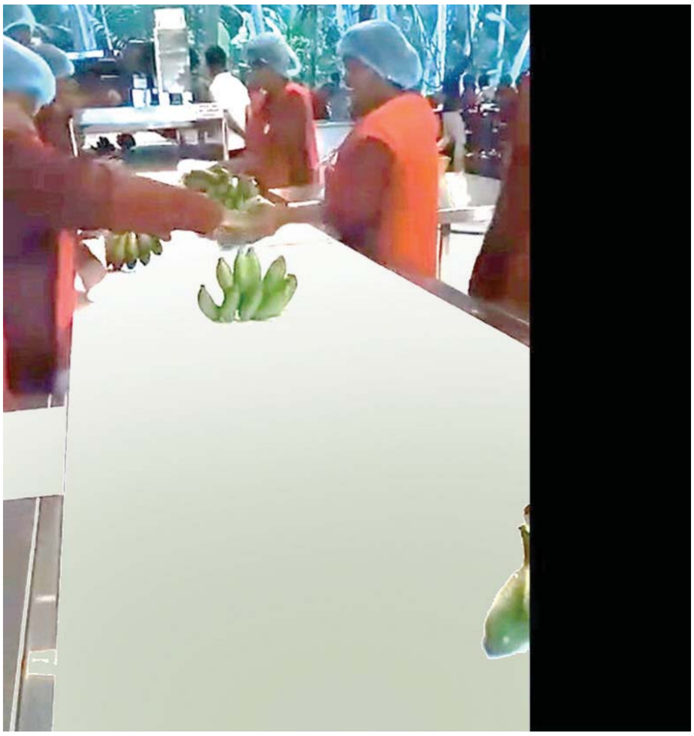
The processes that treat the products from arrival from the field are summarized in the following steps:

1. Raw material Reception /Weighing
2. First Selection (Culling)
3. Washing
4. Disinfection
5. Drying
6. Selection and Classification (Grading)
7. Labelling, Packaging and Weighing
8. Finished Product Shipping or Storage in Cold Rooms

FLOW DIAGRAM – POST HARVEST FRUIT TREATMENT



Bananas must be protected from exposure to direct sunlight while they wait for transport to the packinghouse. On most farms, the fruit may wait from 30 minutes to 4 hours before they are transported to the packinghouse. Therefore, direct sunlight exposure must be avoided since it results in sunburn and higher flesh temperatures, which in turn accelerates ripening and shortens potential shelf life.



Bananas hands are offloaded to the packinghouse in field crates. Upon arrival at the packinghouse, Bananas are transferred into a water tank for cleaning. In the tank, they are brushed or gently scrubbed to remove soil, latex, and other organic materials. Selection of off size and poor-quality fruit happens at this time as well. The fruits are next placed into a second tank with water containing approximately 70 to 100 ppm of chlorine to remove any latex remaining and for disinfection. Afterwards, the bananas are placed to drain on a belt conveyor with drain holes. This conveyor goes through a drying tunnel equipped with fans to remove excess water. The fruit ends up on a wider and smooth, food grade type, belt conveyor for grading and packing by weight and size in accordance with buyer standards and/or requirements. Grading allows for the removal of Bananas that are misshaped, bruised, cut, or have signs of decay. Bananas are packed into ventilated, single-layer cartons with or without lids. The openings in the cartons are important to ensure uniform temperature and humidity during storage and shipping.

16.6 Packing House Sanitation

Fresh produce such as bananas can be contaminated with pathogens and other harmful agents when the packing house is not thoroughly clean and sanitized, especially surfaces that come in direct contact with the produce. Cleaning agents such as bleach in a 5% solution are used to scrub surfaces clean, including those that remain wet during the packing process. The cleaning and sanitizing process includes four steps:

- Surfaces should be rinsed so any obvious dirt and debris are removed.
- Apply an appropriate detergent and scrub the surface.
- Rinse the surface with water that is the microbial equivalent of drinking water (potable).
- Apply an appropriate sanitizer. If the sanitizer requires a final rinse, this will require an extra step. Let the surface air dry.

Access to the packing house must be restricted to personnel involved in the packing operation. Other people and animals are not allowed inside. Packing personnel must wear appropriate protective clothing and head gear and must maintain good hygiene and health.

The packing shed must be protected from rainfall and wind-borne contamination such as dust. The surrounding areas must be treated if necessary to avoid any type of contamination.

Packing House Sanitation

17. QUALITY ASSURANCE SYSTEM FOR BANANAS

Annex 4 contains a Quality Assurance protocol for Bananas, together with a list of the most common banana defects in Sri Lanka. It also describes how to make a quality evaluation based on a physical inspection of the fruit.

18. EXPORT PROTOCOL

18.1 Banana Containers

Bananas are shipped in reefer containers. These containers provide refrigeration to protect the quality and prolong the shelf life of the produce. The quantity of 13.3-Kg banana boxes that can be shipped depends on the type of reefer and the configuration of the cargo:

	Normal Reefer			High Cube Reefer		
Reefer	**Pallets**	**Boxes**	**BB Bxs**	**Pallets**	**Boxes**	**BB Bxs**
20-Ft	10	700	840	10	770	924
40-Ft	20	1,400	1,610	20	1,540	1,771

BB = Break Bulk

The configuration of the cargo varies a great deal as well:

Reefer	Type	Pallets	Break Bulk
20-Ft	Normal	7x10x10	7*12*10
	High Cube	7x11x10	7*12*11
40-Ft	Normal	7x10x20	7*23*10
	High Cube	7x11x20	7*23*11

Reefer containers will take a few more boxes in a break bulk configuration, but most clients prefer palletized bananas. There is usually an upfront charge for palletized fruit to offset the cost.

The temperature for holding and shipping bananas is 13 °C under normal atmosphere conditions. For controlled atmosphere shipping, the temperature is 14 °C.

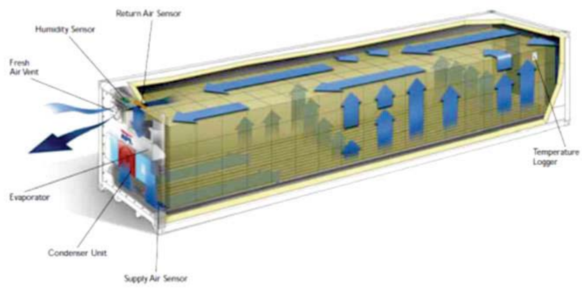
Ambul bananas have been shipped successfully to the Middle East at 10 °C.

The ventilation setting for a reefer container should be set at 25% (97 m^3/hr to 116 m^3/hr) for short trips such as from Sri Lanka to the Middle East and 15% (56 m^3/hr to 67 m^3/hr) for long trips.

Containers must be thoroughly checked for damage and operational readiness before loading. In addition, they must be pre-cooled and completely scrubbed clean and sanitized with a 5% bleach solution, or similar, to receive the cargo. It is important to make sure they remain in optimum condition and free from foreign invaders such as insects all throughout the loading process.

Reefer Container

Reefer Container Settings Panel



Reefer Container Cool Air Flow

Temperature Monitoring Device

Loading Bananas in Reefer Container

Loading Reefer Container into Boat

18.2 Mixed Bananas Containers

Shipping volumes of small bananas such as Ambul from Sri Lanka to the Middle East are relatively small presently. The industry will grow in production gradually as the farmers learn about the new production technologies being introduced and as exports of small volumes are successful. It will take some time until a significant number of reefer containers can be loaded full of small bananas in Sri Lanka on a weekly basis.

Fortunately, bananas can be shipped in small volumes together with other compatible products such as King Coconut. This alternative will benefit the small banana export industry because it will assure weekly deliveries of small bananas that will create supply confidence in the Sri Lankan product in the international market.

18.3 Banana Ripening Protocol

Ehylene concentration should be 150 ppm to 200 ppm
Lower pulp temperature to 13 C - 14 C before applying ethylene

	Ripening Days								
	0	1	2	3	4	5	6	7	8
3 Days Cycle	Lower Pulp Temperature to 13 C - 14 C	Ethylene 18 C	18 C	17 C					
4 Days Cycle	Lower Pulp Temperature to 13 C - 14 C	Ethylene 18 C	18 C	17 C	15 C				
5 Days Cycle	Lower Pulp Temperature to 13 C - 14 C	Ethylene 17 C	17 C	17 C	17 C	15 C			
6 Days Cycle	Lower Pulp Temperature to 13 C - 14 C	Ethylene 17 C	17 C	17 C	15 C	15 C	14 C		
7 Days Cycle	Lower Pulp Temperature to 13 C - 14 C	Ethylene 15 C	15 C	15 C	15 C	15 C	14 C	14 C	
8 Days Cycle	Lower Pulp Temperature to 13 C - 14 C	Ethylene 14 C	14 C	14 C	14 C	14 C	14 C	14 C	14 C
	0	1	2	3	4	5	6	7	8
	Ripening Days								

Ventilate ripening chamber every day for 15 minutes to evacuate accumulated excess ethylele gas
Store ripe bananas at 13 °C

19. COST-BENEFIT ANALYSIS

AMBUL BANANA

Table 5: Farmer Level Cost Benefit Analysis for Ambul Banana

Item	Unit	Without project	With Project
Fresh Production /ha	MT	17	50
Investment/ha	LKR	433,440	601,456
Cost/Kg	LKR	34	37.6
Gross Income/ha	LKR	535,500	1,120,000
Net Income/ha	LKR	102,060	518,544
Gross Margin per kg	LKR	6	26
Benefit/Cost Ratio		**1.2**	**1.9**

CAVENDISH BANANA

Table 6: Farmer Level Cost Benefit Analysis for Cavendish Banana

Item	Unit	Without project	With Project
Fresh Production /ha	mt	19.8	50
Production Waste	%	25%	25%
Sales Volume/ha	MT	14.9	37.5
Cost of Production/ ha	LKR	535,298	1,754,423
Cost/Kg	LKR	36	47
Selling Price/Kg	LKR	110	180
Gross Income/ ha	LKR	1,639.200	6,750,000
Gross Margin/ ha	LKR	1,103,902	4,995,577
Benefit/Cost Ratio		**3.0**	**3.8**

KOLLIKUTU BANANA

Table 7: Farmer Level Cost Benefit Analysis for Kollikutu Banana

Item	Unit	Without project	With Project
Fresh Production /ha	mt	17	50
Investment/ha	LKR	433,440	601,456
Cost/Kg	LKR	41	37
Gross Income/ha	LKR	504,000	7,200,000
Net Income/ha	LKR	330,624	5,696,361
Gross Margin per kg	LKR	79	142
Benefit/Cost Ratio		**2.9**	**4.8**

Annex 1: Specifications for Banana Saplings for the ASMP Banana Clusters

1. Bidders must have to be registered with the Department of Agriculture as a planting material producer and supplier under the Seed and Planting material Act.
2. Basic biological materials for tissue culture plantlet production must have to be taken from a Cavendish banana plantation where Dole Lanka purchases banana fruit products for their export programs and must have a link to the biological material for tissue culture plantlet production originally brought by Dole Lanka to Sri Lanka. Supplier must verify such link.
3. Producers must have followed all steps of the recognized international protocol for their tissue culture plantlet production. Producer must verify such protocol.
4. Producer must have scientifically and biologically recognized laboratory and enough capacity to plant hardening facilities to produce tissue culture plantlets and his hygienic and phytosanitary production conditions (Free from viruses/ Free from Mutations) and environment must have to be well maintained according to international standards. Producers must verify such conditions.
5. Having experience in supplying tissue cultured Cavendish banana seedlings to commercial cultivations projects within the last three years will be considered as a special qualification when selecting a bidder. Producer must specify such conditions by the Names, Dates, and quantities.
6. If selected, bidder must provide Cavendish banana saplings according to the below mentioned characteristics achieved approximately in a 3-month second hardening period.
   a. Saplings must be healthy and vigorous and free from pests and diseases.
   b. A pseudo stem must be 30 to 40 cm in height and 2.0 to 3.0 cm in diameter.
   c. Saplings must have 4 to 5 broad and well-developed dark green leaves with at least two of them having a width of least 10 cm to 15 cm.
   d. Saplings must be potted in 250-gauge black colour polythene bags with at least 20 cm height with 11.5 cm Diameter (7.5" H x 4.25" Dia).
   e. Root system must be well developed.
7. It is the responsibility of the supplier to transport the saplings quantities to the place notified by the caller institute. Supplier must provide suitable transport facilities for the same. The bidder must also be produced the cost of transportation separately.
8. The bidding process also includes a practical observation of the bidder's plant production process. Random samples will be tested for banana virus by the Plant Virus Index Centre (PVIC) and it is the bidder's responsibility to bear the costs for testing and to prepare all production sites and records for this purpose.
9. In the event of any issue or a problem with this procurement process, the decision of the Project Director of Agriculture Modernization Project will be the final.


Annex 2: Production of Ambul Banana Planting Material Using "Peepers"

Peepers are very small banana followers or suckers that are removed from the mother plant and then are grown under nursery conditions as Ambul banana planting material.

Selection of Peepers

Peepers are collected in the field from selected mothers as follows:

The field from where peepers will be collected must be free from pests and diseases.

The mother plants in the chosen field must be vigorous and healthy looking.

The fruit from these mother plants must have the accepted fruit size, appearance, and condition of Ambul banana for export (true Ambul banana fruit genotype).

Peepers must be at least 15 cm to 20 cm in height to be collected, must have a healthy and vigorous appearance and must be free of pests and diseases.

Nursery Procedure

2-3.5 litres black polyethylene bags filled ¾ full potting mix are used to grow the peepers. The mix is made up of soil, river sand and coconut husk in a 3:1:1 proportion. In addition, 20 gm of 12-5-20 complete fertilizer is added to the potting mix. Water is applied morning and afternoon, avoiding water logging in the bags. A foliar fertilizer containing major and minor nutrients such as Ino-K is applied on a weekly basis once the plantlets become established in the bags.

The major pest in a banana nursery is the stem borer weevil (*Odoisporus longicollis*), controlled by applying Tridex (50 ml/20 ltr, 500 gm/ltr Trichlorfon) or Venom (21 ml/20 ltr, 100 gm/ltr Bifenthrin) sprayed on the nursery floor and around the stems of the small plants. Usually, 2 applications are sufficient; however, population counts are required to ensure the treatment is being effective.

Care must be taken to apply additional Nitrogen (N), either in granular or liquid form, if N deficiency symptoms appear on the plants. For this purpose, a water-soluble N source is preferred such as Ca $(NO_3)_2$. A solution is made applied using 36 gm/ltr and 100 ml are applied on top of the soil per bag.

Transplanting

Meristems from peepers are ready for the permanent field once they reach a height of 30 cm to 40 cm and have at least 3 to 4 well developed leaves. It is important not to under-grow or over-grow the meristems since this will definitely affect the vigour of the first-year plantation. Meristems must be transferred to the permanent production site as soon as they reach the physiological stage for transplanting.

Annex 3: Fertigation Protocol

Management of the Irrigation System

1. Turn irrigation pump on and allow the operating pressure of the system to become stable at the correct operating pressure (1 Bar to 2 Bar).
2. When pressure is stable, make sure venturi system is working correctly using only water in the fertigation tank or container.
3. Once venturi system is checked, proceed to fertigate with the fertilizer solution.
4. After fertigation, allow the system to continue to apply irrigation water to the plot for at least 10 minutes in order to flush out any fertilizer solution residue remaining in the system.

5. Make sure to apply Phosphoric acid every two weeks as recommended to make sure system remains unclogged by deposits of calcium salts.

Using Fertigation Solutions

1. Carefully follow "Irrigation and Fertigation Recommendations" issued by the ISP to make sure the right amounts and types of fertilizer materials are used for fertigation.
2. To prepare the fertigation solution, accurately weigh the correct amounts of fertilizer materials using a portable weighing scale.
3. Mix the weighed fertilizer material with water in an appropriate container such as a 20-liter plastic bucket using a clean wooden stick to stir the fertilizer material into the water to make sure all the fertilizer material is dissolved.
4. In case there is a fertilizer material that is not 100% soluble in water such as TSP, mix for at least 5 minutes to dissolve as much material as possible.
5. Filter the fertigation solution into the fertigation container to be used with the venturi system (fertigation tank or container) using a cloth filter such as an old t-shirt or similar.
6. After filtering, the fertilizer material left on the cloth filter when using a partially soluble fertilizer material such as TSP must be saved into a container to be used in the next fertigation with the same material.

7. Close the main valve of the irrigation system and open the valves of the venturi system to force the irrigation water to flow through the venturi system. This will create the necessary vacuum to suck the fertigation solution into the irrigation system to be distributed throughout the plot and applied to the crop.
8. After the fertigation solution is applied, add clean water to the fertigation container and allow this water to flow though the venturi system to clean it.
9. Open the main valve and close the venturi system valves to allow for normal irrigation to resume.

Annex 4: Soil Analysis Results and Fertigation Recommendations for Banana Clusters

SOIL ANALYSIS RESULTS FOR RAJANGANAYA BANANAS

Crop	Sample Code	Lab No.	1:2.5 H2O	%	µS/cm	Exchangeable (meq/100g)			Available (ppm)						cmol/Kg					
			pH	OM	EC	Ca	Mg	K	NH4-N	P	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Ca/K	Mg/K	Ca+Mg/Kg	Ca Sat
Bananas	Rajanganaya Yaya 01	B10431	7.66	2.69	98.3	5.24	3.13	0.34	24.0	26	9.6	304.5	50.6	2.2	8.7	1.7	15.4	9.2	24.6	60.2
Bananas	Rajanganaya Yaya 02	R1 432	7.49	2.55	227.0	7.11	3.37	0.38	23.8	46	9.0	252.6	66.8	4.0	10.9	2.1	18.7	8.9	27.6	65.5
Bananas	Rajanganaya Yaya 03	R2 432	7.49	2.96	151.6	8.47	3.82	0.44	18.3	41	11.6	273.6	48.0	2.8	12.7	2.2	19.3	8.7	27.9	66.5
Bananas	Rajanganaya Yaya 04	R3 433	7.38	2.15	207.0	8.42	3.80	0.68	17.1	214	9.4	296.0	50.4	2.9	12.9	2.2	12.4	5.6	18.0	65.3
Bananas	Rajanganaya Yaya 05	R4 434	7.23	2.82	303.0	10.93	4.25	1.21	38.0	89	8.9	269.3	76.2	6.0	16.4	2.6	9.0	3.5	12.5	66.7

Interpretation:

- K is low in 4 out of 5 sites
- Cu deficient in 4 out 5 sites
- Zn very deficient in all sites
- Ca/Mg ratio very narrow in favor of Mg
- Ca/K ratio narrow in two sites
- Mg/K ratio generally high in favor of Mg

Fertlizers:

N

K Applications of K are required both for low K and for cation unbalances, except for Track 5

Foliar micronutrients, mostly Cu and Zn, but specially Zn are required

CaSO4 Applications of Ca may be required to increase the Ca/Mg ratio. SO4 will lower pH as well

Kg/ Sub-Plot A/ Application	1-3 Months	4-12 Months	One Year +
Urea	0.34	0.51	0.68
TSP	0.02	0.04	0.05
MOP	0.86	0.65	0.86
$CaSO_4$	0.36	0.27	0.36
Applications per Week	2		
Phosphoric Acid (ml)	58.4	87.6	116.8
Application of foliar micronutrients every two weeks, especially Cu and Zn			
Do not apply MOP in track 5. Need to continue monitoring K level through soil and foliar analyses.			

Table 8: Fertigation Recommendations per Application per Half Acre Plot

SOIL TESTS RESULTS FOR JAFFNA AND MULLAITIVU BANANAS

Analytical report on Soil FM/AR4 - REPORT CIC/0037/21-22

Sample received on 03/07/2021
sanple Ref: 37/CIC/0003/21-22
Description of Sample : Moderate wet soil (06) Samples were collected by client,
sample tested on: 18/08/2021- 21/08/2021
Tests performed accotrding to ASI Methods and Walkley Black Method

	Code		1:2.5, H_20	%	µS/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/hg					
Site	Sample	LAB NO	pH	OM	EC	Ca	Mg	K	NH_4-N	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Mg/K	Ca+Mg/K	Ca+Mg+K	Ca Sat.
KK Bana	MU-III	R4 432	6.4	1.61	45.5	3.28	0.89	0.33	26.8	23	43	7.1	234.4	55.7	5.3	4.7	3.69	2.70	12.64	4.50	69.79
Am Bana	JF-II	R8 432	6.96	3.09	243.0	11.61	1.14	0.5	31.8	101	38	9.5	56.4	77.3	8.9	13.25	10.18	2.28	25.50	13.25	87.62

Interpretation:

Low Organic Matter in Mullaitivu
Low Magnesium in Mullaitivu
Very low Potassium levels in both Clusters
Sulphur, Copper and Zinc are deficient
Ca/Mg Ration in Mullaitivu is very Narrow

Recommendations:

Apply Nitrogen as required by the crop
Mg/SO4 applications are required in Mullaitivu
MOP is required in both Clusters

Foliar applications of micronutrients are necessary

Kg/ Sub-Plot A/ Application	1-3 Months	4-12 Months	One Year +
Urea	0.34	0.51	0.68
MOP	0.55	0.82	1.10
$MgSO_4$	0.39	0.59	0.78
Applications per Week	2		
Phosphoric Acid (ml)	50	50	50
Application of foliar micronutrients every two weeks, especially Cu and Zn			

Table 9: Fertigation Recommendations per Application per Half Acre Plot

Fertilizer recommendations for Jaffna are not given because Jaffna Bananas is an Organic Cluster and organic fertilizers have no guaranteed content in Sri Lanka. They also do not have a formulation to calculate the quantities of different nutrients to be applied.

BATTICALOA BANANAS

Agriculture Sector Modernization Project - ASMP
Analytical Report on Soil
Description of sample(s): Moderate wet soil
Test(s) performed according to: Agro Services Internation (ASI) Methods and Walkely, and Black Method

Sample Reference: 72/CIC/0004/21-22
Sample tested on: 10/12/2021 - 13/12/2021

			1:2.5, H20	%	µ5/cm	Exchangeable (meq/100g)			Total %	Available (ppm)						cmol/kg	Cation Ratios				
Crop	Sample Code	Lab No.	pH	OM	Ec	Ca	Mg	K	N	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mag	Ca/K	Mg/K	Ca+Mg/K	Ca Saturation
Banana	1. Vellaveli - Malayarkaddu	R3 435	5.77	1.48	86.4	1.78	0.63	0.71	0.17	72	32	8.0	345.9	57.8	3.1	3.52	2.8	2.5	0.9	3.4	50.6
Banana	2. Vellaveli - Sinnawaththai	R4 435	5.70	1.21	89.1	1.83	0.71	0.86	0.17	90	29	9.0	272.2	47.3	2.8	3.80	2.6	2.1	0.8	3.0	48.2
Banana	3. Vellaveli - Thikkodai	R5 435	6.05	0.67	54.7	3.29	2.01	0.45	0.01	29	19	9.8	262.3	25.0	1.6	5.95	1.6	7.3	4.5	11.8	55.3
Banana	4. Vellaveli - Vilanthoddam	R6 435	5.98	1.08	46.2	1.77	0.69	0.38	0.11	51	27	6.1	215.5	44.7	3.3	3.24	2.6	4.7	1.8	6.5	54.6
Banana	5. Vellaveli - Palayadivaddai	R7 435	5.90	1.88	46.9	1.89	0.64	0.60	0.11	43	34	6.5	170.3	39.0	4.1	3.53	3.0	3.2	1.1	4.2	53.5
Banana	6. Vellaveli - Vammiyadiuththu	R8 435	5.97	1.34	37.5	1.97	0.72	0.66	0.11	35	27	5.3	153.7	29.5	1.7	3.75	2.7	3.0	1.1	4.1	52.5

Interpretation:

Organic matter and N are low. N very low
Ca, Mg and K are low
S and Mn are rather low
Cu and Zn are at deficient levels. Very low
Cation ratios show Mg unfavored by ratios
Ca Saturation a bit low, but Ca ratios favor Ca

Fertilizer Recommendations:

Organic matter like compost must be applied
Apply N as required by crop
MOP, CaSO4 and MgSO4 and need to be applied as well
Foliar applications of micronutrients, especially Cu and Zn are urgently needed
TSP is required only in Chenkalady - Thalawai as basal soil applications in granular form
The amounts of fertilizer to be applied will vary by crop
Specific recommendations will be made by crop

Kg/ Sub-Plot A/ Application	1-3 Months	4-12 Months	One Year +
Urea	0.23	0.34	0.45
MOP	0.31	0.47	0.63
CaS_2O_4	0.12	0.18	0.24
$MgSO_4$	0.12	0.18	0.24
Applications per Week	3		
Phosphoric Acid (ml)	50	50	50
Application of foliar micronutrients every two weeks, especially Cu and Zn			

Table 10: Fertigation Recommendations per Application per Half Acre Plot

SOIL ANALYSIS RESULTS FOR MONORAGALA

		1:2.5, H_2O	%	µS/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/kg					
Sample Code	Lab No.	pH	OM	EC	Ca	Mg	K	N	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Ca/K	Mg/K	Ca+Mg/K	Ca %
Banana Sewanagala	W4 435	5.93	0.94	60.6	4.4	1.51	0.5	73.3	33	18	11.2	273.6	56	1.6	6.81	2.91	8.80	3.02	11.82	64.61
Mango Siyabalanduwa	W5 435	6.3	1.21	214	6.68	3.5	3.15	53.2	371	19	6.3	412	60	5.5	13.53	1.91	2.12	1.11	3.23	49.37

Low or deficient nutrient

Interpretation:
Organic matter low except in two locations
K very low in Sewanagala
S, Cu and Zn generally low;
Cation ratios out of optimal ranges. Mg dominates

Fertilization:
N required regardless of levels of Organic Matter and soluble N
Phosphoric Acid will prevent irrigation system from clogging and will also add P to the soil and

MOP will add K much needed in Sewanagala
CaSO4 Will lower the dominance of Mg in the soil exchange complex and will provide required S
Foliar Micro. Will address micro nutrient deficiencies

Important to add compost during land preparation to increase Organic Matter levels

Kg/ Sub-Plot A/ Application	1-3 Months	4-12 Months	One Year +
Urea	0.34	0.51	0.68
MOP	0.43	0.65	0.86
CaS_2O_4	0.18	0.27	0.36
Applications per Week	2		
Phosphoric Acid (ml)	50	50	50
Application of foliar micronutrients every two weeks, especially Cu and Zn			

Table 11: Fertigation Recommendations per Application per Half Acre Plot

Annex 5: Protocol for Fungicide spraying for Sigatoka Control

Spraying Cycles

Three (3) fungicide spraying cycles will be applied as follows:

Cycle 1: Folicur (Tebuconazole)

Cyclen2: Daconil (Chlorothalonil)

Cycle 3: Folicur (Tebuconazole)

Days between cycles:

10 days

The status of the Sigatoka infection will be assessed in each farm after the 3rd cycle to determine if further spraying cycles are required.

Fungicide dosage and spraying rate per acre:

COMMERCIAL NAME	ACTIVE INGREDIENT	TYPE	DOSAGE/100 lt OF WATER	APPLICATION RATE
FOLICUR	TEBUCONAZOLE	SYSTEMIC	170 ml	40 LT /acre
DACONIL	CHLORATHALONIL	CONTACT	200 ml	
SURFACTANT (ADYUVANT)			As Label indications	

Safety Requirements:

The following protective elements must be used by the operators doing the fungicide application:

- Protective mask
- Eye protective glasses
- Rubber gloves
- Rubber boots
- Long sleeve shirt
- Long trousers
- Hat

Operators must take a shower or bath immediately after finishing the spraying.

Application must be done with a power pressure sprayer equipped with fine spray nozzle.

MIST BLOWERS CANNOT BE USED.

Annex 6: Quality Assurance System for Bananas

Introduction

Quality is, perhaps, the main attribute the produce market desires. It is also a tool for producers and distributors to distinguish themselves among each other to gain positioning in the market and increase long term demand for their produce. A common language on quality is also important for communication to take placed among fresh produce supply chain participants. Thus, a good quality assurance system provides the means for those involved in the produce business to manage quality. It all begins with a quality score given by a numeric value that facilitates comparisons and provides a feedback mechanism for improvements to be made down the supply chain. The quality score facilitates communication, together with the factors that affect quality, described, and analyzed in the system.

There are four major components of a good quality assurance system:

1. Compliance with produce specifications such as packaging and appearance and condition requirements such as size (length and girth)

2. The number of units meeting specifications (PUMS) expressed as percent makes up the quality score.
3. The analysis of defects, the main instrument to provide feedback throughout the value chain to set in motion necessary improvements to maintain the high-quality standards demanded by the market.
4. The inspection forms that are the data collection and analysis tools used by the system.

Components of the Quality Assurance System

Compliance with Product Specifications

There are very well-defined specifications for Cavendish bananas in international markets. However, there are few specifications for small or baby bananas such as Ambul.

The table below lists the specifications by the *CODEX Alimentarius* for Cavendish bananas, categorized in three classes. The EU follows these specifications. The US has similar requirements.

Class	Specifications	Tolerances
Extra or Premium	Bananas in this class must be of superior quality. They must be characteristic of the variety and/or commercial type. The fingers must be free of defects, except for very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.	Five percent by number or weight of bananas not satisfying the requirements of the class, but meeting those of Class I or, exceptionally, coming within the tolerances of that class.
Class I	Bananas in this class must be of good quality. They must be characteristic of the variety. The following slight defects of the fingers, however, may be allowed, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package: • slight defects in shape and colour. • slight skin defects due to rubbing and other superficial defects not exceeding 2 cm2 of the total surface area. The defects must not, in any case, affect the flesh of the fruit.	Ten percent by number or weight of bananas not satisfying the requirements of the class, but meeting those of Class II or, exceptionally, coming within the tolerances of that class.
	This class includes bananas which do not qualify for inclusion in the higher classes, but satisfy the minimum requirements specified in Section 2.1 above. The following	

Class	Specifications	Tolerances
Class II	defects, however, may be allowed, provided the bananas retain their essential characteristics as regards the quality, the keeping quality and presentation: • defects in shape and colour, provided the product retains the normal characteristics of bananas. • skin defects due to scraping, scabs, rubbing, blemishes or other causes not exceeding 4 cm2 of the total surface area. The defects must not, in any case, affect the flesh of the fruit.	Ten percent by number or weight of bananas satisfying neither the requirements of the class nor the minimum requirements, with the exception of produce affected by rotting, major imperfections or any other deterioration rendering it unfit for consumption.

Despite the above and commercially, the main requirement for any banana is the weight of the box, the condition and appearance of the bananas inside the box, the condition of the packed box, the quality of the box materials, the minimum finger length and the minimum calliper of the fruit, the count of units in the box for either clusters or hands, etc.

The Number of Units Meeting Specifications (UMS)

The quality score is given by the UMS compared to the number of units inspected expressed as percent i.e., a box of bananas packed in hands and having a count of 6 with 5 of them meeting specifications upon inspection is given a quality score of 83.3%. Buyers differ in their demands for a quality score. Usually, the highest demand when loading a container at origin is 90% and the lowest, 80%. Fruit arriving at the market should have a UMS of 90% or higher.

Analysis of Defects

As the units are examined to obtain the quality score, the different defects affecting the quality are tallied. This creates a distribution of defects which is the main component of the feedback loop that a good quality assurance system utilizes. The defects are categorized into those common at the farm and those appearing during handling after harvest. The distribution also highlights those defects that are the main cause for diminishing quality at the time the inspection is done. When quality assurance records are properly kept, the seasonality of the incidence of defects is established as well. This knowledge allows for preventive measures to be taken before seasonal defects become detractors of quality.

To develop a distribution of defects, a defect list is created. Then, every defect is defined, and tolerance levels are established. Pictures of the damage caused by the defect complete the defects database (Annex 1). A listing of the most common banana defects follows:

			Quality Defects Specification		
DEFECTS	**Code**	**Measure**	**A**	**B**	**C**
Bruising	**BR**	Area	Clean	Clean	Affects the Pulp of the Fruits
Chemical Injury / Burn	**CI/ CB**	Area	Clean	1.5 Label	> 1.5 Label
Corky Scab	**CS**	Area	1.5 Label	1.5-2 Label	> 2 Label
Flowers	**FL**	Finger	Clean	1 or 2 per Hand	3 or > 3 per Hand
Gel Latex	**LG**	Area	1.5 Label	1.5-2 Label	> 2 Label
Harvesting Knife Cut	**KT**	Finger	Clean	Clean	No Tolerance
Latex Stain New	**LSN**	Area	1.5 Label	1.5-2 Label	> 2 Label
Latex Stain Old	**LSO**	Area	1.5 Label	1.5-2 Label	> 2 Label
Leaf Scar	**LF**	Area	1.5 Label	1.5-2 Label	> 2 Label

Malformed Finger	MFF	Finger	Clean	1 Finger	2 or More
Malformed Hand	MFH	Area			
Maturity Stain	MS	Area	1.5 Label	1.5-3 Label	> 3 Label
Mutilated Finger	MF	Finger	Clean	Clean	No Tolerance
Neck Injury	NI	Finger	Clean	Clean	No Tolerance
Neck Stump	NS	Finger	Clean	Clean	No Tolerance
Nipple Like	NL	Finger	Clean	1-49%	>49 %
Over Cal	OC	Finger	Clean	Clean	>48
P House Knife Cut	CT	Finger	Clean	Clean	No Tolerance
Scarring New / Old	SRN / SRO	Area	1.5 Label	1.5-2 Label	> 2 Label
Speckling	SK	Area	1.5 Label	1.5-2 Label	> 2 Label
Split Peel / Split Finger	SP	Finger	Clean	Clean	No Tolerance
Sunburn	SU	Area	Clean	Clean	No Tolerance
Tip Constriction/ Mokillo	TC	Finger	Clean	Clean	No Tolerance
Too Few Fingers	TF	Finger	Clean	Clean	No Tolerance
Too Short	TS	Finger	Clean	Clean	<6.5 inch
Under Cal	UC	Finger	Clean	Clean	<39
Yellow Blossom End	YB	Finger	Clean	Clean	No Tolerance

A=Specification B=Tolerance C=Out of Specification

Below is an example of a distribution of defects after packing that shows Neck Injury (NI) and Scaring New (SRN) are the main defects of concern for the inspection. NI is mostly a packing defect and SRN was probably caused during the harvesting and transfer of the fruit to the packing shed. The results of this inspection are good feedback for the packers at the packing shed and the harvesting crews in the field to minimize the damage to the fruit.

Neck Injury	NI Count	25
Over	OC Count	11
Bruising	BR Count	8
Mutilated finger	MF Count	5
Scaring New	SRN Count	23
Too Short	TS Count	10
Mutilated Hand	MH Count	2
Scaring Old	SRO Count	6
Maturity Stain	MS Count	3
Corky Scab	CS Count	5
Speckling	SPK Count	11
Red Rust	RR count	4
Mokillo	TC Count	4
Total		117

Inspection Forms

The final component of the quality assurance system is made up of the inspection forms. Usually there are two types of forms, one for compliance with product specifications (Annex 1) and the other one for the analysis of defects (Annex 2).

Annex 2 and Annex 3 show samples of the compliance and defects forms used to perform a quality assurance inspection at any place in the supply chain from farm to supermarket. The defects form can be modified for the most common defects, according to the situation.

Inspection Procedure

A sample size of 5% of the commercial units packed or shipped (boxes) is taken for quality assurance inspections. For fruit in a 20-ft reefer container that holds 700 to 750 boxes, 35 to 38 boxes should be inspected. Inspections can also be done based only on numbers of units (clusters, hands, etc.). The quality score, then, reflects UMS as a portion of the total units inspected.

A team of 2 inspectors performs the inspections, one records and tallies while the other one calls of the out defects. They should switch roles in the next inspection. At packing, it is recommended to do at least 2 inspections, one in the morning and the second in the afternoon.

The packing house inspectors should continuously feedback information to the harvesters according to the results of the inspections during packing for corrective measures to be implemented quickly i.e., the inspections could be showing recent bruising damage from the harvesting that could be prevented during the harvest operation.

Quality inspections can also be done in different places along the supply chain. Arrival inspections are as common as packing inspections. The results of these inspections are fed back to the farms and other components of the supply chain. Boxes are selected for inspection as they are off-loaded from the shipping containers.

Applicability of the System

This quality assurance system for bananas is applicable to any other fruits and vegetables that are marketed whole, in units or packed in containers. However, a relevant defect s list and data base needs to be developed for the product(s) of interest.

Compliance Form

QUALITY ASSURANCE SYSTEM - COMPLIANCE FORM

Place: ____________________

Date: ____________________ Time: ____________________

Farm ( ) Port ( ) Other: ____________________

Pulp Temperature (if applicable): __________

Box Weight (Kg): __________

Fruit Condition: Hard Green ( ) Turning ( ) Ripe ( )
Fresh: ( ) Clean: ( ) Healthy: ( )
Explain: ____________________

Pack

Correct:	( )	Well Filled:	Tight pack, well filled	( )
High:	( )	Fairly Well Filled:	Tight enough, well filled	( )
Low:	( )	Slack:	Loose, not well filled	( )

Label Placement:
Correct: ( )
Incorrect: ( )

PLU Placement:
Correct: ( )
Incorrect: ( )

Box Materials
Comply with Box Specifications ( ) Do Not Comply ( )
Explain; ____________________

Box Markings:
Compliant: ( ) Non Compliant: ( )
Explain: ____________________

Units: Hands ( ) Clusters: ( )

Number of Units per Box: __________

Caliper Grade: __________ __________ __________ __________
Finger Length: __________ __________ __________ __________

Inspector:
Name ____________________
Signature ____________________

Defects Form

QUALITY ASSURANCE SYSTEM - DEFECTS FORM

Place: ______________________ **Units:** Boxes ( ) Hands: ( ) Clusters: ( )

Date: ______________ Time: ______________

Farm ( ) Port ( ) Other: ______________ **Quality Score (UMS):**______________

	DEFECTS												
Unit	**SF**	**UG**	**OG**	**SCN**	**SCO**	**BRN**	**BRO**	**NI**	**CS**	**FL**	**LDN**	**LDO**	**Total**
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
Total													
Percent													

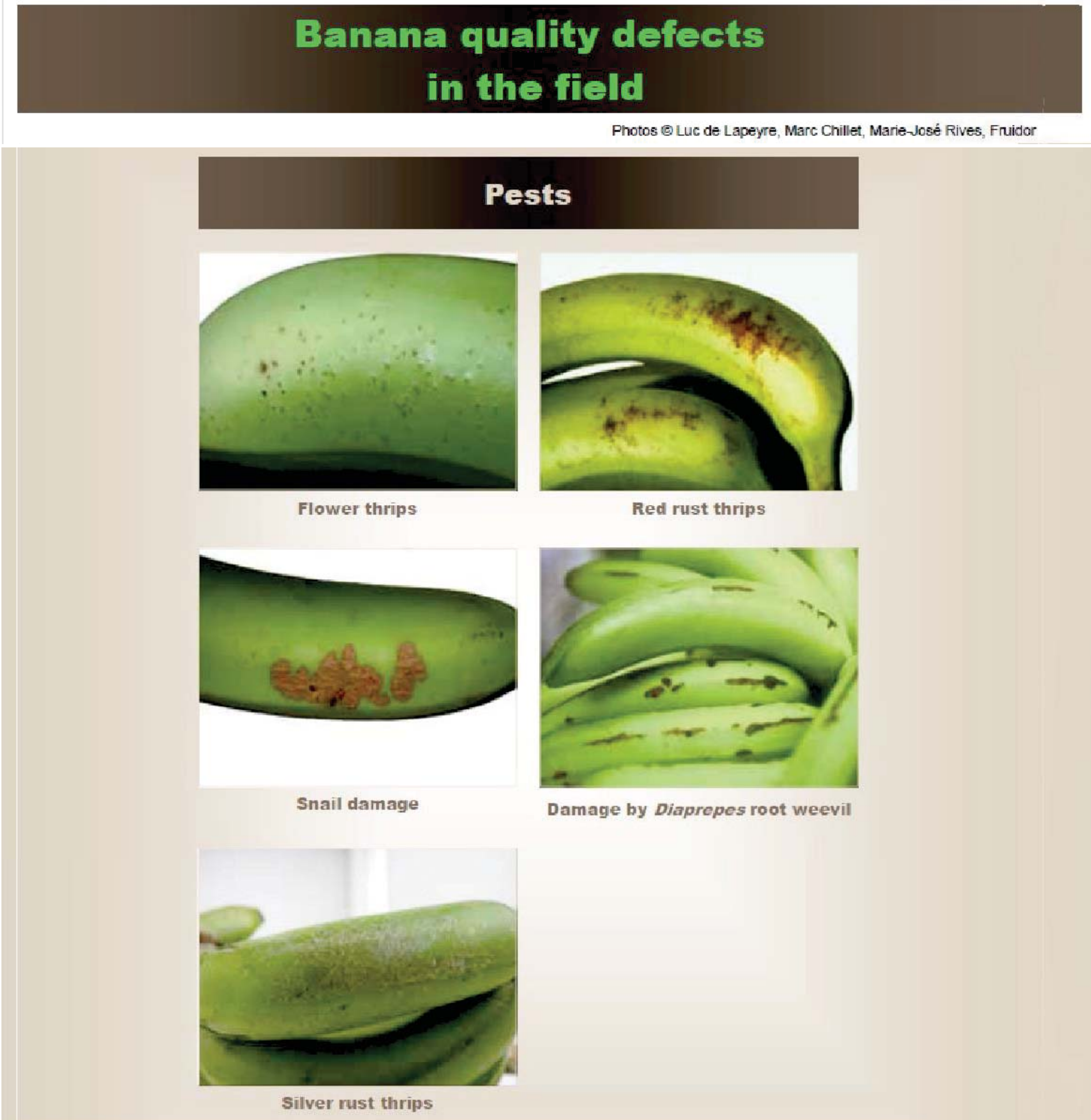
SF Short Fingers **UG** Under Grade **OG** Over Grade **SCN** Scarring New **SCO** Scarring Old **BRN** Bruising New **BRO** Bruising Old **NI** Neck Injury **CS** Corky Scab **FL** Flowers **LDN** Latex Damage New **LDO** Latex Damage Old

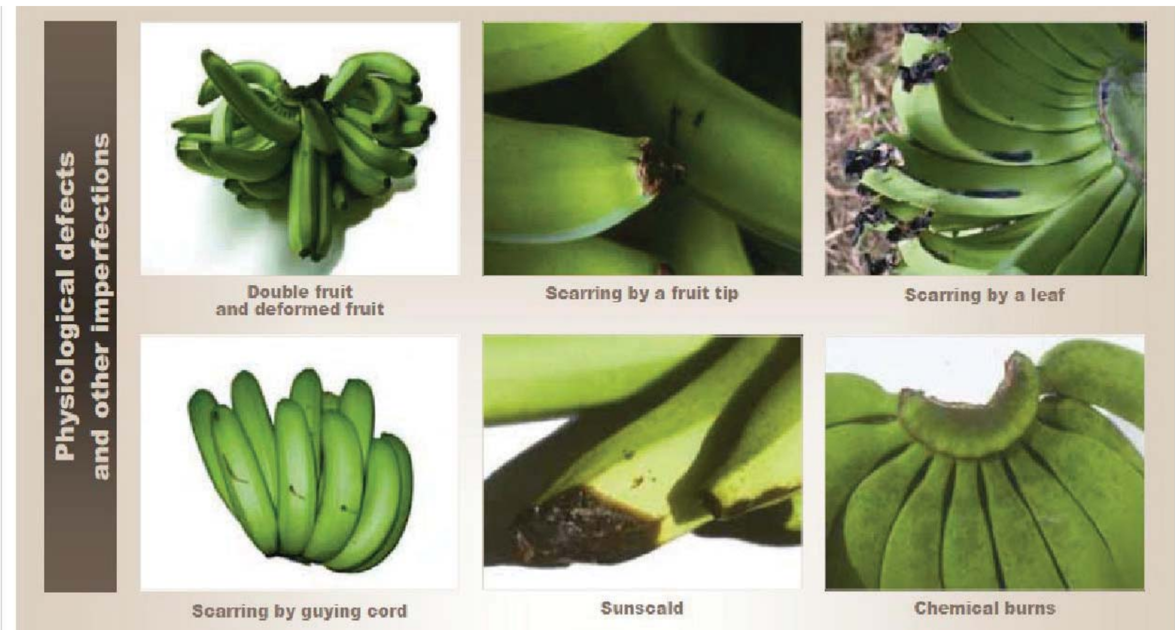
Inspector:

Name ______________________

Signature ______________________

Common Defects on Bananas





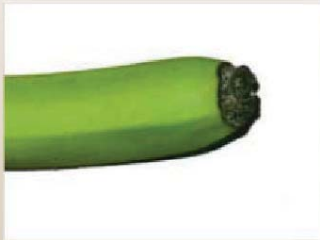
Diseases


Speckle


Red speckling at ripening


Deightoniella


Sooty mould on fruit stalk


Cigar-end rot

Banana quality defects at packing

Photos © Luc de Lapeyre, Marc Chillet, Marie-José Rives, Fruidor

Selection problems and miscellaneous defects


Fruit too thin


Fruit too short


Incomplete flower removal

Latex stains

Bruising


Flexed fruit stalks


Bruising caused by impact during packing

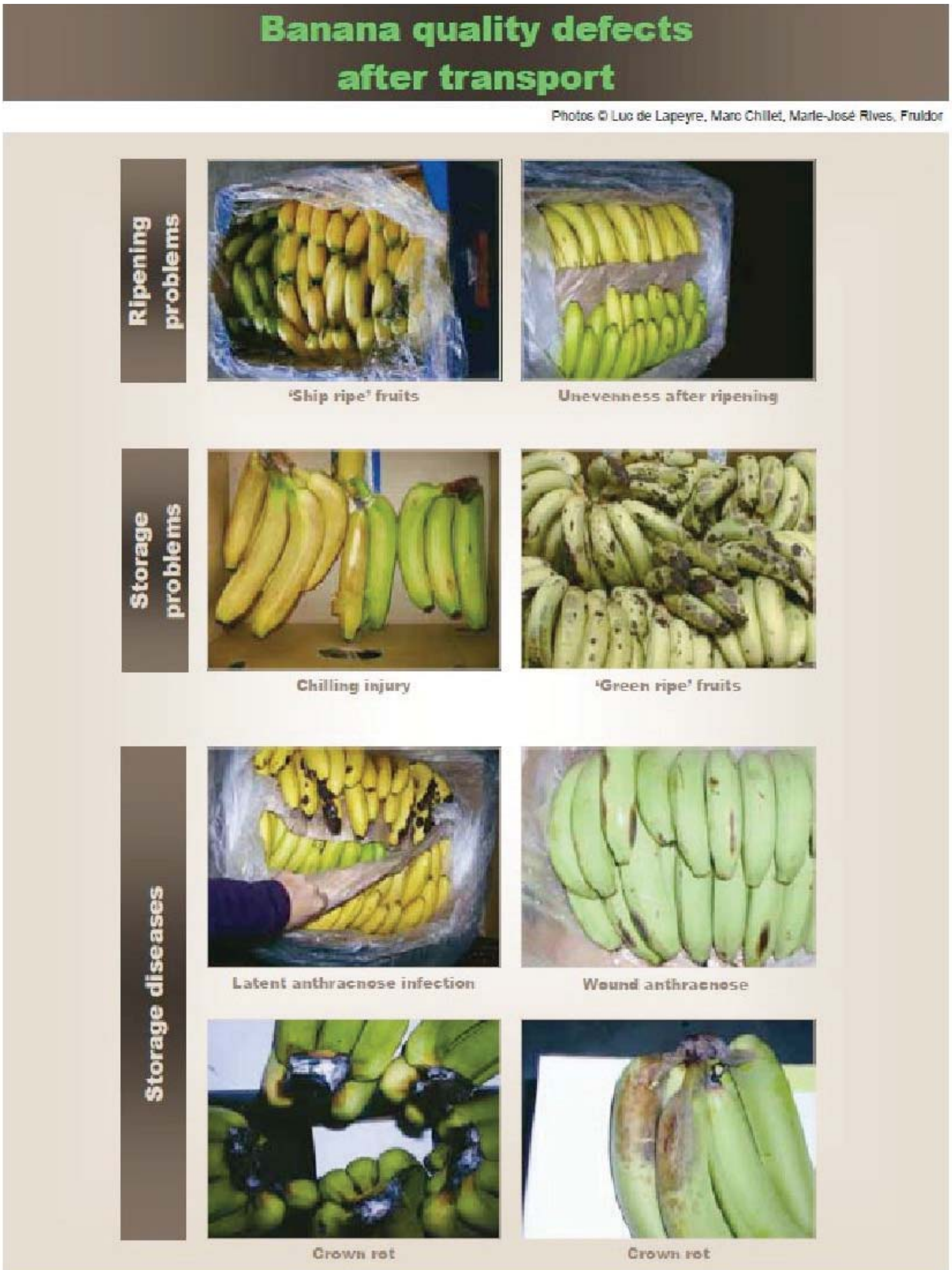
Dehanding problems


Crown cut too short


Pointed crown


Detached crown


Knife wound


Banana quality defects
after transport
Photos © Luc de Lapeyre, Marc Chillet, Marie-José Rives, Fruidor
Ripening problems
'Ship ripe' fruits
Unevenness after ripening
Storage problems
Chilling injury
'Green ripe' fruits
Storage diseases
Latent anthracnose infection
Wound anthracnose
Crown rot
Crown rot