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MINISTRY OF AGRICULTURE, LIVESTOCK, LANDS AND IRRIGATION

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Agriculture Sector Modernization Project

OPERATIONAL MANUAL

MANGO

AGRICULTURE SECTOR MODERNIZATION PROJECT

PARK
AGRICULTURE TECHNOLOGY DEMONSTRATION PARK

Prepared by -
Dr. Julian Velez - International Agronomist
FCG New Zealand (FCG ANZDEC Ltd.)

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PROJECT DIRECTOR'S MESSAGE

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

Contents

1. INTRODUCTION

Mango is a stone fruit which belongs to the Anacardiaceae family, which are flowering plants that produce fruits. Mangos are native to South Asia and is the national fruit of India, Pakistan, and the Philippines.

1.1 Optimal Ecological Requirements

- Altitude: 0 m – 1,500 m above sea level.
- Rainfall: 500 mm – 1,000 mm annually
- Growing Temperature: 24 ^{0}C – 27 ^{0}C
- pH range: 5.5 – 7.5

Mangos can be grown in a wide range of soil types, from light sandy loams to red clay. Deep, rich, well-drained soils provide the best production and fruit quality. Some farmers plant trees on sloping sites to prevent waterlogging the root system.

2. LAND PREPARATION

2.1 Primary Land Preparation

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

2.2 Secondary Land Preparation

1. Heavy Soil Textures
   - Disk harrow using a disk harrow implement with disks having a diameter of 40 cm.
   - Two passes perpendicular to each other are required.
2. Light Soil Textures
   - Cultivate using a tine tiller implement.
   - 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
   - Sloping handmade ditches to evacuate water from rainfall quickly, 30 cm wide x 15 cm deep.
   - 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.
   - 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.

- 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
    - Sloping drainage secondary canals 45 cm wide x 30 cm deep at 20 m intervals
    - 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
    - Drainage lines 45 cm wide and 45 cm to 60 cm deep at 5 m to 10 m intervals
    - 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
    - Backhoe excavator or similar with 30cm or 45cm wide bucket

3. VARIETIES

The TJC mango variety was discovered in Sri Lanka by Tom Ellawala among a collection of varieties planted by him in his orchard in the early 1990's. Within his collection of varieties, he selected the one he knew would succeed commercially and named it TomEJC. It later became to be known as TJC. The Department of Agriculture officially recognized the TJC variety in 2003. Since then, TJC has become the more widely cultivated mango variety in Sri Lanka in the Dry and Intermediate agri-ecological zones.

Figure 1: TJC Mango

The TJC mango fruit is characterized by a deep golden flesh with a smooth yellow skin. The flavour is excellent, and the fibre content is low, making the pulp smooth and fleshy. The ratio of flesh to seed is large meaning there is more flesh to eat. In addition, the ripening rate of the fruit is slow making the TJC the preferred variety for export. The average weight of a fruit is 600 grams, meaning fruits weighing over one Kg are common. The TJC mango season runs for seven to eight months, from June to January.

4. PLANTING MATERIAL

Certified grafted plants are the best planting material. Saplings must be at least 50 cm high, with a girth of at least 5 mm and must have 2 or 3 nodes with well-developed but tender small branches with dark green leaves. The plant must reflect the characters of its variety (Annex 1).

All planting material must be free from pests and diseases.

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.

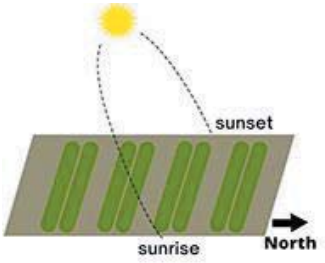


Figure 2: East to West orientation of rows

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.

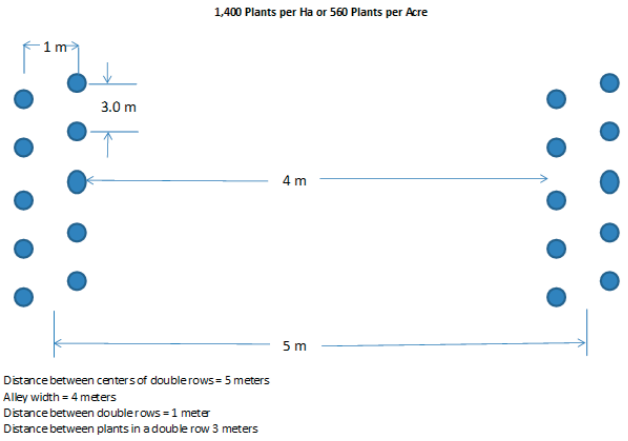


Figure 3: Double Row High Density Planting of Mango

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 paper 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 mango plant as required depending on rainfall.

5.2 Plant Spacings within the Double Rows

TJC Mango	3.00 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 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 the hole size 30 cm x 30 cm x 30 cm or one cubic foot.

6. IRRIGATION AND FERTIGATION

6.1 Irrigation

Figure 4: Micro-Sprinkler System

Mango requires 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.

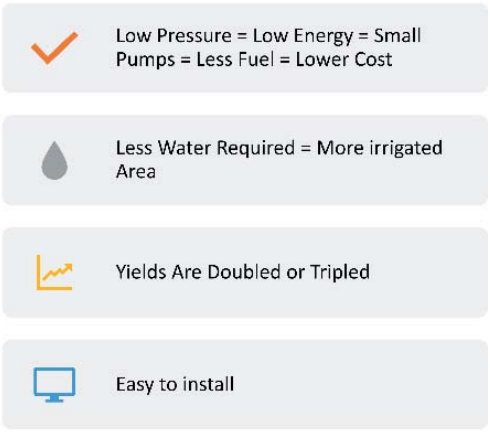


Figure 5: Advantages of low-pressure irrigation

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.

6.2 New Irrigation Concepts

- Net Area Irrigation: Water for cultivated area only
- Evapo-transpiration for irrigation scheduling rather than soil moisture content.
    - Consumptive water uses 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 mango consumptive water use of 9 mm of water per day is equivalent to 63 mm per week. This weekly amount can be applied in three cycles. Under this application regime, the chart below is the recommended irrigation time per cycle to irrigate mango using the micro sprinkler system:

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

Table 1: Irrigation schedule

6.4 Fertigation

A mango tree requires the right kind of nutrition 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 trees fast, allowing for a rapid up take by the mango trees 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 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 3 contains all the soil tests and the global fertilizer recommendations for the mango Clusters. The results of the Dambulla Cluster in Matale District tests below will illustrate the process followed to formulate a fertigation program for mango in Matale:

Organic matter low except in Govigammanaya/Lenawa and Nikawatana
Potassium (K) is somewhat low except in Alakola Wewa and Nikawatana
Phosphorus (P) is very low in Eraula and marginal in two other locations
Sulphur (S), Copper (Cu) and Zinc (Zn) are deficient in general
Cation ratios out of optimal ranges. Magnesium (Mg) dominates the exchange complex

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

Nitrogen (N) required regardless of levels of Organic Matter and soluble N in the soil
Phosphoric Acid will add Phosphorous (P) to the soil and will prevent irrigation system from clogging
TSP will supply required Phosphorous (P) in most locations
MOP will supply the Potassium (K) required in most locations
Calcium Sulphate (CaSO4) as a soil amendment will lower the dominance of Mg in the soil exchange complex and will provide required Sulphur (S)
Micronutrient applications are necessary to address micronutrient deficiencies

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 Matale, therefore, lacks low amounts of Potassium, about 0.13 meq of Potassium.

This required level of Potassium (0.13 meq) can be converted to an application rate of 105 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 0.1346 meq of Potassium are 52.5 ppm (390*0.1346).
- This value of 52.5 ppm of Potassium is, then, multiplied by 2 to give 105 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 amount of nutrients to be applied is:

Recommendation	N	P	K	Ca
Kg/ Ha	126	55	105	100
Lb/ acre	126	55	105	100
Kg/ acre	57.3	25.0	47.7	45.5

Table 2: Nutrition Quantities

For these amounts, the quantities of fertilizer materials per year (season) are:

Kg/ Acre	Urea	P Acid	TSP	MOP	$CaSO_4$
Fertilizer per year (Season)	125	29	27	96	207

Table 3: Quantities of fertilizer materials per year (season)

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	Year 1-2	Year 3-5	Year 6+
Urea	1.0	1.7	1.6
P Acid	1.0	1.7	0.8
TSP	1.0	1.7	0.8
MOP	1.0	1.7	2.4
CaSO4	1.0	1.0	1.0

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

Kg/Acre	Year 1-2	Year 3-5	Year 6+
Urea	125	208	203
P Acid	29	48	23
TSP	27	45	22
MOP	96	160	234
$CaSO_4$	207	207	207

Table 4: Quantities of fertilizer as per stage of development

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 Mango crop. Therefore, the amounts of fertilizer required per week are:

Kg/Acre/Week	Year 1-2	Year 3-5	Year 6+
Urea	4.8	8.0	7.8
P Acid	2.2	3.7	1.8
TSP	1.0	1.7	0.9
MOP	3.7	6.2	9.0
$CaSO_4$	7.9	7.9	7.9

Table 5: Week-wise, fertilizer quantities

These amounts are to be applied in 2 cycles per week. As per application basis (irrigation cycle), the amounts of fertilizer materials required are:

Kg/Acre/Application	Year 1-2	Year 3-5	Year 6+
Urea	2.4	4.0	3.9
P Acid	2.2	3.7	1.8
TSP	0.5	0.9	0.4
MOP	1.8	3.1	4.5
$CaSO_4$	4.0	4.0	4.0

Table 6: Fertilizer quantities, as per application basis (irrigation cycle)

These amounts are further reduced based on the net area cultivated in Mangos. 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 7: Fertigation Recommendations per Application per Half Acre Plot

Kg/ Plot/ Application	Year 1-2	Year 3-5	Year 6+
Urea	0.27	0.44	0.43
TSP	0.06	0.10	0.05
MOP	0.20	0.34	0.50
$CaSO_4$	0.44	0.44	0.44
Application per week	2		
Phosphoric Acid (ml) ***Application every two week***	145	242.1	118.9
Foliar Applications of Micronutrients every two weeks are recommended, especially Cu and Zn			

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. PEST AND DISEASE CONTROL

IPM concepts and practices must be applied to manage mango pests and diseases. The quantity/intensity factor is a practical and easy to apply IPM concept and helps 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 mango pests and diseases found by ISP during implementation of the ASMP in Sri Lanka are:

8.1 FRUIT FLY

Scientific name: *Ceratitis* spp./*Bactrocera invadens*

Identification

- Adult fruit flies are small, about 4 to 7 mm long, dull brownish yellow to brownish black with red eyes in some species.
- Yellowish flies that are commonly attracted to fermenting fruit of all kinds.
- Female fruit flies puncture the peel of mature fruit and lay eggs under the skin of mature and ripening fruits.
- Eggs hatch in 1 – 2 days.
- The larvae grow and feed on mango fruits.
- The larvae are about 6 – 7 mm long and can be found in very ripe culled and damaged fruit in the fields.

Figure 6: Fruit Fly

Damage

- Fruit flies cause direct damage by puncturing the fruit skin to lay eggs.
- During egg laying, bacteria from the intestinal flora of the fly are introduced into the fruit. These bacteria cause rotting of the tissues surrounding the egg.
- The eggs hatch, maggots feed on the fruit flesh making galleries. These provide entry for pathogens and increase fruit decay.
- Fruit dropping to the ground just before the maggots pupate.
- Premature ripening of fruits.

Damage to the fruits starts during egg-laying. The punctures on the fruit are not readily recognizable. However, after four to five days, soft brownish spots appear, liquid oozes from the spots and the underlying tissue rots. The continuous feeding of the larva and the secondary microbial activity further destroy the fruit making it unsuitable for consumption.

Control

- Collect all fallen fruits and destroy by burying them at least 50 cm deep or put them in a drum of water with 1 inch oil for 2 weeks. Spray with Deltamethrin (DECIS2.5 EC®) etc. The chemicals can be mixed with hydrolysed protein at a rate of 200 – 1,000 ml/tree or sugar/ molasses and sprayed to act as bait.
- Bag the fruits with appropriate bagging materials.
- Harvest mangoes before they become ripe (mature green stage). Fruit flies are attracted to them as soon as their surfaces become yellow.
- Use of fruit fly traps such as Auto Dissemination Device (ADD) by Real IPM, Hydrolysed protein (CERA TRAP).
- Use of natural enemies, especially parasitic wasps (Diachasmimorpha Longi Caudata, Fopius arisanus etc.).
- Post-harvest Hot Water Treatment (HWT): Dip fruits in a hot water tank. This treatment must follow quarantine protocols, established by the importing countries, for temperature and dipping time. Temperature is usually set 46 C and the dipping time will vary according to the size of the fruit. For small fruit, 75 minutes and for large fruit, 90 minutes.
- Do not intercrop with the following fruits trees: guava, papaya, jackfruit, sineguelas and santol since they are also preferred hosts of the fruit flies.

Fruit flies can be a problem in certain growing regions and may limit distribution of the harvested fruit. For example, mangos produced in Hawaii are not permitted in the U.S. mainland, Japan, or other markets because of quarantine restrictions due to fruit flies and mango seed weevil. Mangos from other regions are treated in a hot water bath following harvest to eliminate pests and protect the fruit from decay.

8.2 MEALY BUGS

Scientific name: *Rastrococcus spp.*

Identification

- Mealy bugs are small (2 mm long), oval-shaped, flat, soft-bodied insects with white cottony filaments on their body
- Their body is covered with a white woolly secretion.
- Male adult mealy bugs have two wings while females are wingless.
- They are usually found on flushes, flowers, and fruits.
- Mealy bugs have a symbiotic relationship with red ants. They excrete sticky fluid called “honeydew”, which serves as food for red ants. The ants protect and transport mealy bugs to the different parts of the tree.

Figure 7: Mealy Bugs

Damage

- They suck vital plant sap from tender leaves, petioles, and fruits.
- Seriously attacked leaves turn yellow and eventually dry and fall off.
- This can lead to shedding leaves, inflorescences, and young fruit.
- Mealybugs excrete honeydew on which sooty mould develops. The honeydew produced by the mealy bugs promotes growth of sooty moulds on leaves, which eventually affects the photosynthetic activity.

Control

- Attempt to dislodge mealybugs from affected plant parts by hosing them off with soapy water applied with a hose with pressure.
- Destroy affected parts at the beginning of the infestation.
- Heavily infested branches may be pruned to control the pest, especially on the tender branches before flowering begins.
- Conserve natural enemies.
- Insecticides do not generally provide adequate control of mealybugs owing to their wax coating.
- Common insecticides to control mealybugs include Admire, Actara, Neem extract and Neem oil.
- Destroy ant nests inside the plantation or in the proximity.

8.3 Anthracnose

Fungal disease caused by *Colletotrichum spp. / Gloeosporium spp. / Glomerella spp. / Sphaceloma (Elsinoe) spp.* Anthracnose is a major post-harvest problem of mango fruits and is the most serious fungal disease of mangoes in Sri Lanka.

Description

- Mango anthracnose is caused by the fungus during humid conditions.
- Prevalent during flowering and fruit set.
- The anthracnose fungus can be re-activated in response to physiological changes associated with ripening, resulting in the development of lesions with subsequent spoilage of the fruit.

Symptoms

Anthracnose causes irregular brown spots on young leaves while mature leaves get distorted with “shot holes” in various shapes and sizes. It also blackens and withers the flowers and produces “blossom blight” while causing brown to black sunken spots on the fruits.

In addition:

- Occurs on leaves, twigs, petioles, flower clusters (panicles) and fruits.
- On Leaves, Petioles, Twigs and Stems:
  - ✓ Lesions start as small angular brown to black spots that can enlarge to form extensive dead areas.
  - ✓ Infection of young leaf flushes may show up as lesions along the margins of the young bronze or pale green leaves, in which case they are semi-circular in shape.
  - ✓ In very humid weather, new twigs may show a dark affected area from the tip backwards, sometimes with defoliation of the young shoots.
- On Panicles
  - ✓ Small black to dark-brown spots that enlarge, coalesce, and kill the flowers before fruit set.

- On Fruits
  - ✓ Affected fruits develop sunken, prominent, dark brown to black decay spots before or after picking.

Other damage caused by anthracnose includes:

- Reduced tree vigour.
- unproductive terminal branches.
- withering of flowers.
- failure to set and retain fruits.
- rotting of fruits.
- total crop failure.

Control

- Follow recommended cultural practice to maintain vigorous and productive trees, which are less prone to diseases.
- Maintain good light penetration and air circulation in each mango tree.
- Collect and burn trash to reduce sources of disease.
- Bag fruits using appropriate bagging materials to reduce further field infestation.
- Fertilize and irrigate trees to improve tree vigour.
- When flushing occurs on rainy days, protect emerging flushes from leaf spots by spraying registered contact fungicides. DO NOT use systemic fungicides.
- Apply protectants/systemic fungicides to protect inflorescence against blossom blight and fruit rot infection on developing fruits. Amistar can be used as a systemic fungicide using a localized application directed to the flowers panicle at a rate of 16 ml for 16 L of water. The fungicide is applied using a hand spray container.
- Remove and destroy dead twigs and branches.
- Post-harvest Treatment:
  - ✓ Hot Water Dip: Dip fruits for 10 minutes at 53 °C to 55 °C water.
  - ✓ For 1 minute if water temperature is between 59 to 60oC.
  - ✓ Store fruits in a cool place.
  - ✓ Pesticides: Carbendazim 500g/L (BENDAZIM 500 SC, RONDAZIM)

8.4 IPM Cultural Practices that Reduce the Use of Pesticides

a) Pruning of crowded branches (after harvest) allows light penetration and improves air circulation, creating an environment unfavourable for pest development.

b) Field Sanitation: Under brushing and clearing of surroundings.

c) Fertilization and Irrigation to improve tree vigour.

d) Vigorous trees are less prone to infection from anthracnose and other pests.

e) Fruit Bagging to minimize the use of insecticides and enhance fruit quality.

f) Collection and proper disposal of fruit droppings such as fallen fruits. Dispose of them properly by either burying or burning. They can also be removed physically from the plantation These practices prevent the pests inside the fruits from completing their life cycle.

9. PRUNING

9.1 Tree Architecture

- Tree architecture or formative training begins when the seedlings are about 0.9 m high (waist high).
- At that time, the top of the central leader young trunk is cut off to encourage the lateral growth of branches.
- 3 – 4 lateral branches are left to grow to about 20 cm and then are cut off as well to encourage another tier of lateral branches to grow outwards and produce fruit.
- The preferred tree architecture for trees in a high-density system is a rectangular box.
- For such architecture, the optimum tree size is 2 m wide and 3 m tall. Additional height and width (branching) must be restricted.
- Mango plants should develop into strong and well-shaped trees within the first 3 to 4 years.
- After tree maturity, selective short pruning of branches may be required to encourage growth of lateral branches that better supports fruit production, maintaining, at all costs, the box architecture of the tree.

9.2 Box Pruning (Slim Hedge System)

Since mangoes are terminal bloomers, branching must be promoted with priority. Thus, when pruning, tip every branch. Every cut creates 3 or 4 buds in every terminal. This means 3 or 4 chances for a bloom.

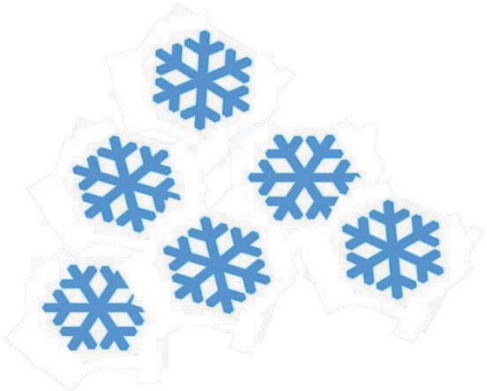


Figure 8: Branching Architecture

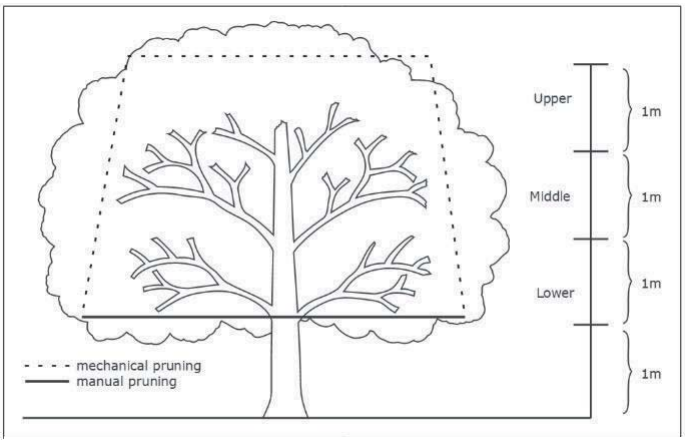


Figure 9: Box Pruning Architecture

- Gibberellic acid (GA) is a floral inhibitor that prevents a mature mango tree from flowering. This inhibitor for bud break is produced in the roots of the tree and is exported up to the terminal buds. The more buds, the lower the concentration of the inhibitor per bud and the more fruit a tree will have i.e., 1 bud 10 units of inhibitor; 10 buds, 1 unit. A high number of buds will, then, guarantee fruiting.
- Prune every tree as soon as the fruit comes off. In other words, the best time for pruning is right after the harvest, unless pruning is practiced advancing or to delay fruit production in the next fruiting season.
- Young trees do not require a great deal of shaping after the proper "box" architecture is obtained. They need to be pruned as a bush to maintain the desired shape and create a large number of growing points or buds. These buds turn into earlier fruiting and more fruiting.
- Pruning must lead to less wood and more leaves. That is the objective of pruning. In fact, pruning every year should take off about ¼ of the canopy when one practices pruning for less wood and more leaves.
- A rule of thumb is to recycle the box canopy every 4 years. To achieve this goal, one major limb must be taken off per year. Take off branches that grow unruly as well. Something drastic must be done every year even with the use of a saw.

- The tree must be kept calm. It must not grow large. It must produce fruit. Small trees pruned for more buds produce more fruit. Large trees use most of the energy producing and maintaining wood and their fruiting rate is lower.
- It is important to take wood out to allow more buds to fruit. This is the reason pruning large trees is more complicated than pruning young trees. That is why the tree must be kept small.

9.3 Pruning Mature Trees Bearing Fruits

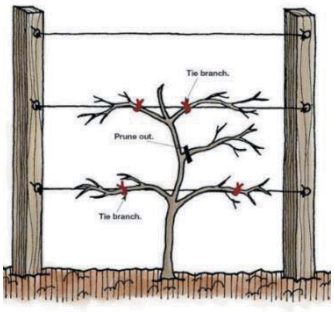
- Remove crowded branches or those that are already dried up; affected by insect pests and diseases.
- It should be done, preferably, during summer after harvest.
- It should be done only within the canopy.
- Avoid excessive pruning on fruit-bearing trees, minimal pruning for small trees and open centre for big trees.
- To change the variety or to rejuvenate old trees, drastic pruning is recommended.

9.4 Espalier Trellis System

The espalier trellis allows for the total control of the architecture and growth of the mango tree to make it easier to manage i.e., spraying, pruning, harvesting, and other practices are made much easier to manage.

Figure 10: Espalier Trellis System

The espalier trellis production system for mango is made up of one dominant central trunk and lateral branches tied along a wire which is secured to wooden posts.



Annex 4 contains a pictorial step by step procedure to trellis mango using the Espalier Trellis system.

9.5 De-Blossoming

The process of removing flowers in very young mango trees. This makes possible the proper development of the tree canopy.

10. INTERCROPPING

- The double row and high-density planting are very well suited for intercrops with the mano trees in the 4 m alley between double rows.
- Intercropping is allowed until the coverage of the mango tree canopy affects the growth and development of the intercrop by shading.
- Intercrops of short-lived fruit trees, such as papaya, or 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 mango fruit begins in earnest.
- Intercropping with crops that share common pests and diseases must be avoided. The use of chemicals that can harm the mango tree 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).

11. FLOWER INDUCTION

Fruit	Growth Regulators	Chemicals	Pruning	Other
Mango	Paclobutrazol	KNO_3	Synchronized pruning of terminal branches	Irrigation Stress

Table 8: Flower Induction

There are mainly four ways to induce flowering, chemical and physiological stress:

- Applying paclobutrazol growth regulator at the base and around the tree (collar drench).
- Spraying the trees with Potassium Nitrate solution when plants are dormant.
- Synchronized pruning of terminal branches after the harvest
- Induced physiological stress:
  - ✓ Deprive the trees of nutrients and/or water.

11.1 Paclobutrazol

The plant growth regulator, paclobutrazol, applied post-harvest in a small amount to the soil at the base of the mango tree significantly promotes flowering and fruiting in the following year. The following benefits from the treatment have been obtained:

- A significant increase in flowering leading to increased yields.
- The early flowering considerably enhanced fruit maturity. Treated trees flowered three to four weeks early, which reduced the time to fruit maturity by at least two weeks.
- Visually, the fruit developed a better external colour.

The application of paclobutrazol to the soil as a drench around the tree trunk (collar drench) is the most effective method, as it ensures proper uptake by the tree. The required quantity is mixed in approximately one litter of water and poured onto the soil around the trunk in a circular band. The ideal time to apply paclobutrazol is soon after harvest. In dry conditions, a light irrigation is recommended after application. Foliar sprays have been ineffective.

The size of trees at first application is important. This depends on the age of the trees and the spacing between them. Apart from promoting flowering, paclobutrazol also restricts tree vigour. Trees should, therefore, be allowed to develop a good canopy before treatment commences. In high tree density situations with closer spacing, it is recommended to apply paclobutrazol early when trees are about three years old. However, when trees are spaced farther apart, say 10 m, early application with paclobutrazol will reduce canopy size and the fruit bearing area. In such a situation, treatment can commence when trees are about five years old. Tree size and canopy fill are important considerations. Large trees, especially seedling trees, respond more slowly than young, bearing, grafted trees. The dosage required also varies between cultivars. For example, Florida cultivars, such as Irwin, Glen and Tommy Atkins require a lower dosage than Kensington Pride.

At excessively high dosages, flower and shoot compaction can lead to increased infestation by caterpillars. If such compaction occurs, the dosage of repeat applications should be reduced., Two sprays of potassium nitrate at 4 g/L at ten-day intervals, commencing at signs of flower bud burst, were found to minimize panicle compaction. However, compaction is best prevented by using an optimum dosage. It is also important to note that tree size and not age is the key factor for determining dosage. Where there is considerable variation in tree size, dosage may have to be varied.

Considering that the amount of Paclobutrazol to use per tree varies primarily according to the size of the tree, a common rule of thumb is to use from 0.5 g to 1 g of Paclobutrazol active ingredient per 1 meter of canopy diameter. These amounts can be diluted in 2 L of water and applied around the tree base as a collar drench.

Currently available commercial names of Paclobutrazol are Cultar and Austar.

Any treatment that leads to increased production should be supported by good management to maintain tree healthy. This includes nutrition, irrigation, control of pests and diseases, pruning and skirting. It is desirable to prune and skirt trees after harvest and before the treatment. Unhealthy and weak trees should not be treated with paclobutrazol.

11.2 Potassium Nitrate

Chemical flower inducer, potassium nitrate (KNO_3) should be applied when the leaves are between 7 and 8 months old, dark green in colour, and brittle.

- Spray KNO_3 or (1-3% concentration) by thoroughly wetting the leaves.
- During the cold and rainy months, use higher concentration (2-3%).
- During the hot months, apply lower concentration (1-1.5%).
- When the tree shows poor flowering response, a follow-up spray using a lower concentration of KNO3 may be applied. This can be done within a week after the first spraying.

11.3 Synchronized Pruning of Terminal Branches

Pruning of terminal branches is usually done soon after harvest to prepare the tree for the next flowering. By accelerating or delaying the time of pruning of the terminal branches after the harvest, tree flowering is also accelerated or delayed (synchronized).

11.4 Induced Physiological Stress

Withholding nutrients like Nitrogen and water to the mango trees will create a physiological stress that will induce flowering. In the case of water, stop irrigation for 1 to 2 months before flowering, then irrigate regularly.

12. BAGGING

Bagging mango fruit is now a common practice to prevent damage from fruit flies, anthracnose, and other pests. Bagging is also helpful to preserve the quality (appearance) of the fruit. Counting the bags placed on the fruit provides a true inventory or count of the mango on the tree. This inventory is determined 12 to 14 weeks before harvest. In other words, the farmer will know three months in advance how much mango he has for the market. When all the farmers bag together, they have a good period to prepare for the harvest, packing and logistics for the local market or for export. They can also plan the pricing and selling of the mango based on the inventory.

In addition, one of the most important quality problems with mango is the variation of internal maturity at harvest time. This problem causes mangoes to have different taste when consumed by the users in the different countries where the mango is exported to. They also ripen to the ready to eat stage at different times. This critical defect can be eliminated by harvesting the mango by age (the number of weeks from bagging). In order to determine the age of the mango at harvest time, it is necessary to use coloured bags.

Every week, a different colour bag is used for tagging the age of the fruit based on an annual colour chart (Coloured Bag Calendar) prepared by management. It is important to use the same chart for all farms (areas) harvesting fruit together. The chart below illustrates the colour sequence and the Colour Bag Calendar from October to December 2023:

Fruits should be bagged between 55 and 60 days after flower induction at the chicken egg size stage.

41	6-Oct	12-Oct	Green	G	
42	13-Oct	19-Oct	Meroon	MR	
43	20-Oct	26-Oct	Yellow	Y	
44	27-Oct	2-Nov	Red	R	
45	3-Nov	9-Nov	Blue	B	
46	10-Nov	16-Nov	Orange	O	
47	17-Nov	23-Nov	Brown with Black Circle	BR/B	
48	24-Nov	30-Nov	Brown	BR	
49	1-Dec	7-Dec	Brown with Green Circl	BR/G	
50	8-Dec	14-Dec			

Table 9: Fruit bagging calendar

12.1 Management of the Fruit Inventory

At the beginning of the farm day, the coloured bags 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 coloured bags 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 coloured bags placed in a week. These counts create a true inventory (fruit inventory) of Mango 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 paper coloured bags 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.

13. HARVESTING

The harvest will be done based on three coloured bags. The farmers will check the 12- and 13-week-old fruit and harvest those that are ready according to the buyer's specifications for maturity index and appearance. All the 14-week-old fruit must be harvested without checking. This age is called the "Sweep" age like in bananas.

This harvesting procedure needs to be adjusted according to the fruit’s growth and development. If the fruit is developing fast, we can reduce the harvesting ages by one week to 11, 12 and 13. If the fruit is growing slowly, we can increase the age by one week i.e., 12, 13 and 14.

If the local market is good, the farmers will want to harvest immature fruit. This is common at the beginning and the end of the harvest season.

Mangos for export are usually picked at the mature green stage to withstand postharvest handling practices. However, the harvest maturity stage may vary with the shipping time to the international markets.

Mangos for export are usually picked at the mature green stage to withstand postharvest handling practices. However, the harvest maturity stage may vary with the shipping time to the international markets.

Mangos are picked by hand or by using a long picking pole which has a canvas or nylon bag attached near a cutting blade to catch the fruit. Ladders and hydraulic lifts are also used to help pickers reach fruit high in the tree canopy.

In general, mango fruits are usually picked before they are fully ripe with the stem intact and after they develop red, orange, or yellow colour. The long stem assures that the internal latex, or juice, does not leak. The fruit is held stem end down on racks or around the tree under the canopy to further prevent latex from dripping on other fruit. The fruit bruises easily and must be handled carefully to avoid damage.

13.1 Harvesting Indexes

- Maturity Period: 12 – 16 weeks after fruit set.
- Some indicators of maturity include:
  - ✓ Well-developed or flattening shoulders and fullness of cheeks.
  - ✓ Presence of "bloom" or powdery deposit.
  - ✓ Yellow green colour near pedicel
  - ✓ Skin changes from green to yellow
  - ✓ The flesh around the seed turns from white to yellow
  - ✓ Sugar content increases
  - ✓ Ready to harvest fruit will float in 1% salt solution (100 grams salt/10 litres of water).

13.2 Harvesting Tips

- Use shears or sharp cutting tools to cut the fruits free from the tree.
- Do not knock or drop the fruits.
- Fruits should be harvested with 2 cm – 4 cm stalks (stems).
- Drain the latex from the fruits by turning.

14. POST-HARVEST HANDLING

14.1 Mango Postharvest Facts

- Mango are climacteric fruits, which means they continue to ripen after harvest.
- The optimal temperature for storing Mango is between 8°C and 10°C (46°F and 50°F). More mature or ready to eat Mango can be stored at 8°C (46°F).
- Mango is sensitive to chilling injury, which can occur when they are stored at temperatures below 8°C (46°F).
- The ideal relative humidity for storing Mango is between 85% and 95%.
- Mango produces ethylene gas, which can cause them to ripen more quickly. Therefore, it's best to store Mango separately from other fruits and vegetables.

14.2 Mango Product Specifications

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

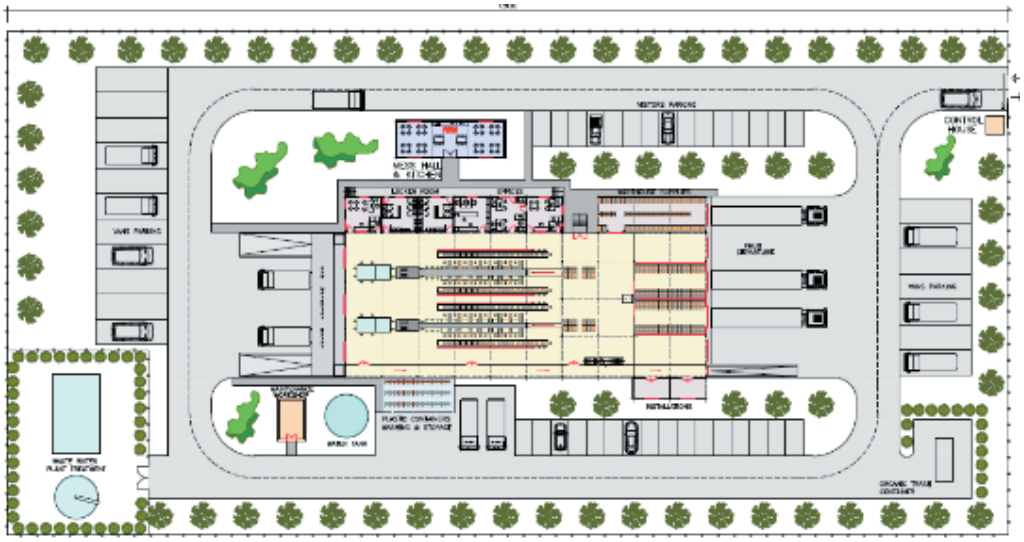
- Export Containers - Corrugated cardboard boxes containing 4.5 Kg net of fruit on arrival.
- Shipping fruit weight - 5 Kg
- Maturity Stage – Mature green to mature depending on voyage time to market.
- Tolerance – 5% to 10% by weight (1 to 2 mango fruits per box).
- Sanitary and Phytosanitary Condition – Fresh and free from blemishes, diseases, and pests.

Count per Box: The Mango market uses the count of fruits per box (count) to differentiate mango sizes and to have a common language to facilitate the exchange and flow of information. Prices vary according to the market and the count:

Count per Box	Mango Weight (gm)
11	455
10	500
9	556
8	625
7	714
6	833

***Based on Shipping Weight of 5 Kg**

14.3 Packing Centre Layout



14.4 Packing 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

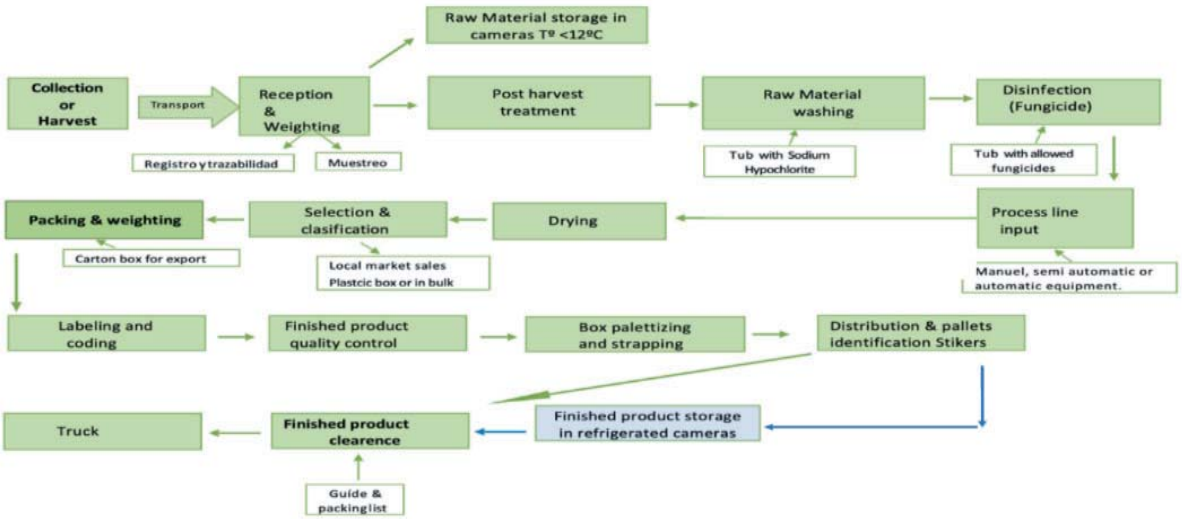


Table 10: Post Harvest Fruit Treatment Flow Diagram

Mangos 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 6 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.

Mangos can either be offloaded to the packinghouse in field crates or from trucks with large cargo holds. Upon arrival at the packinghouse, mangos 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 mango is 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 mangos that are misshaped, bruised, cut, or have signs of decay. Mangos 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.

14.5 Transportation to Packing House Tips

- Containers should be well stacked to avoid any movement.
- Vehicles must always be covered or insulated.
- Vehicles must be cushioned.
- Fruits must be protected from dust, sun, and rain.

Some shippers use a coating of wax to improve natural fruit gloss and reduce water loss during holding and transport.

When a hot water treatment is required, the fruit is pre-sized and placed back into crates. before packing. Then the mangos are immersed in a hot water dump tank for a time period that can range from 75 to 90 minutes, depending on fruit variety, weight, and size. The hot water tank is filled with potable water at 46.1 ºC - 47.8 ºC. Usually, a post-hot water treatment cooling, known as hydrocooling, takes place to rapidly decrease the pulp temperature of the fruit to reduce hot water injury. Hydrocooler water temperatures are usually maintained between 21 °C to 22 °C and the mangos are exposed to the cool water for about 30 minutes. The fruit is then transferred to a packing line for grading and packing.

Hot water treatment is also used for post-harvest Anthracnose control by immersing the mango fruits in a hot water bath at 50 °C for 5 minutes to minimize damage during shipping and distribution.

14.6 Sorting, Cleaning & Grading Tips

- Sorting to remove diseased, mis-shaped, damaged, and unripe fruits and foreign matter.
- Clean with a clean damp cloth
- Grading according to size, colour, and texture

14.7 Packing Tips

- For the export market, pack in single layer in fibreboard cartons of 4 – 5 kg weight.
- The fruits per carton range from 6 – 24.
- The cartons should be well ventilated 5.2 Value Addition

After packing the fruit is palletized if requested by the buyer and then placed in a cold storage room at a temperature 8 °C to 10 °C. The lower temperature is used to preserve mangos with high internal maturity indexes (ready to eat).

Pre-cooling or quick cooling inside the cold storage room to slow down the metabolic processes will extend shelf life. This is done using a forced air tunnel type cooler that forces the cold air of the room through the packed fruit until the fruits quickly cool down to room temperature.

14.8 Packing House Sanitation

Fresh produce such as Mango 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.

Figure 11: Packaging House Sanitation

14.9 Storage Tips

- Mature mangoes are sensitive to chilling injury. There is impaired ripening resulting in poor colour and flavour development at low temperature (5.5 °C)
- Relative Humidity should be maintained at between 85 % – 90 %).

Mangos produced in other countries are often picked at the mature-green stage to withstand the postharvest handling steps required to export them from the production areas to the international market. Upon arrival, this fruit can be treated with ethylene gas in holding chambers in much the same way bananas are held in ripening rooms to induce faster and more uniform ripening and provide ready to-eat mangos that consumers prefer.

15. EXPORT PROTOCOL

15.1 Mango Containers

Mangos are shipped in reefer containers. These containers provide refrigeration to protect the quality and prolong the shelf life of the produce. The quantity of 5 kg mango 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	1,440	1,728	10	1,920	2,304
40-Ft	20	2,880	3,456	20	3,840	4,608

BB = Break Bulk

Pallet configuration is 12 x 12 boxes for a normal reefer and 12 x 16 boxes for a High Cube reefer. Configuration of the cargo in break bulk shipping varies a great deal. Reefer containers will take a few more boxes in a break bulk configuration, but most clients prefer palletized Mango. There is usually an upfront charge for palletized fruit to offset the cost.

The temperature for holding and shipping mango ranges from 8 °C to 10 °C depending on the internal maturity of the fruit and under normal atmosphere conditions. For controlled atmosphere shipping, the temperature could be 12 °C. Mango 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.

Figure 12: Reefer Container

Figure 13: Reefer Container Settings Panel

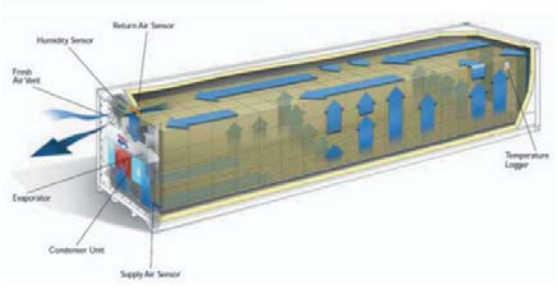


Figure 14: Reefer Container Cool Air Flow

Figure 15: Temperature Monitoring Device

Figure 16: Loading Mango in Reefer Container

15.2 Mixed Mango Containers

Shipping volumes of Mango such as TJC Mango 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 Mango in Sri Lanka on a weekly basis.

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

16. COST – BENEFIT ANALYSIS

Table 11: Farmer Level Cost Benefit Analysis

Production	Unit	Without Project	With project
Fresh Productivity per year	MT	19.8	126
Annual Sales Volume (reduction the waste)	Mt	16.8	107.1
Total cost	LKR	985,418	5,721,850
Production Cost/Kg	LKR	58.7	53.4
Selling Price	LKR/Kg	250	400
Gross income	LKR	4,200,000	42,840,000
Net profit per year	LKR	3,214,582	37,118,150
Benefit/Cost Ratio		3.3	6.5
Average Monthly Income	LKR	267,882	3,093,179

ANNEX 1: SPECIFICATION FOR MANGO PLANTING MATERIAL

Supplier

- Suppliers should own a DoA SCS registered nursery.
- Suppliers should be able transport the plants to the site.
- Supplier should submit a certificate from a reputed laboratory to prove that plants are not infected with Nematode by testing random samples *(Supplier must bear the cost of testing).*
- Preference should be given to suppliers within the district to minimize physical damage in transportation as well as to minimize transportation cost.

Saplings

- Grafted plantlets or saplings from grafted plants must be grown in black coloured polyethylene bags. The size of bags should measure as diameter 12.5 cm and height 20 cm.
- Bags must be filled with compost mixture as the potting media.
- Young grafted Plants should be placed in the centre of the bag to allow for a well-developed root system.
- Seed for root stock for grafting should be obtained from healthy mother plants identified by the range agriculture instructor.
- Certified grafted plants are the best planting material. Saplings from these grafted plants must be at least 50 cm high, with a girth of at least 5 mm and must have 2 or 3 nodes with well-developed but tender small branches with dark green leaves.
- The plant must reflect the characters of the variety.
- Grafted saplings for the permanent field should be free from pests and diseases.

ANNEX 2: 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-litre 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 3: SOIL ANALYSIS RESULTS AND FERTILIZER RECOMMENDATIONS

SOIL ANALYSIS RESULTS FOR MATALE MANGO

	1:2.5, H_2O	%	µS/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/kg						
Sample Code	pH	OM	EC	Ca	Mg	K	N	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Ca/K	Mg/K	Ca+Mg/K	Ca+Mg+K	Ca %
Wawala Area	7.76	1.34	196.3	6.99	5.68	0.95	49.2	25	12	8.9	143.5	17.4	1.9	13.62	1.23	7.36	5.98	13.34	13.62	51.32
Alakola Wewa	7.17	1.61	201	5.12	2.53	1.11	54.4	124	12	11.6	113.7	38	3.4	8.76	2.02	4.61	2.28	6.89	8.76	58.45
Eraula	6.93	0.81	181.5	4.39	1.7	0.96	65	7	19	10.6	105.1	32.4	1.9	7.05	2.58	4.57	1.77	6.34	7.05	62.27
Govigammanaya/Lenawa	6.74	2.02	154.3	2.72	1.28	0.71	73.9	69	21	5.6	257.9	36.3	2	4.71	2.13	3.83	1.80	5.63	4.71	57.75
Welangolla	6.7	0.94	142.1	3.39	1.32	0.64	64.2	118	17	6.7	137.6	38.5	5.4	5.35	2.57	5.30	2.06	7.36	5.35	63.36
Nikawatana	6.74	2.15	171	5.32	1.6	1.3	58.2	21	19	8.5	102.5	22.4	6	8.22	3.33	4.09	1.23	5.32	8.22	64.72

Low or deficient nutrient

Interpretation: Organic matter low except in two locations; K the same; P very low in Eraula and marginal in two other locations; 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	Will add P to the soil and will prevent irrigation system from clogging
TSP	Will addd P required in most locations
MOP	K also required in most locations
CaSO4	Will lower the dominance of Mg in the soil exchange complex and will provide required S
Foliar Micro, specially Cu and Zn	Will address micro nutrient deficiencies

Kg/ Plot/ Application	Year 1-2	Year 3-5	Year 6+
Urea	0.27	0.44	0.43
TSP	0.06	0.10	0.05
MOP	0.20	0.34	0.50
$CaSO_4$	0.44	0.44	0.44
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	145	242.1	118.9
Foliar Applications of micronutrients are required every two weeks, especially Cu and Zn			

Table 12: Fertigation Recommendations per Application and per Half Acre Plot

SOIL ANALYSIS REPORT FOR JAFFNA

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_2O	%	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 Sat.	Ca+Mg+K
Pom	MU-I	R2 432	6.02	1.61	73.6	2.13	0.66	0.23	18.7	22	61	5.3	215.6	21.7	2.7	3.42	3.23	2.87	12.13	62.28	3.02
Papaya	MU-II	R3 432	6.21	1.61	80.7	5.75	1.60	0.69	15.5	2	31	8.4	164.6	73.9	5.9	8.24	3.59	2.32	10.65	69.78	8.04
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	69.79	4.50
Chili	MU-IV	R5 432	6.84	2.15	200.0	7.22	1.81	1.16	31.4	54	28	8.8	212.6	91.6	7.5	10.19	3.99	1.56	7.78	70.85	10.19
Chili	MU-V	R6 432	7.25	2.02	116.4	8.25	5.1	0.24	22.9	36	50	11.4	149.9	83.9	9.5	13.59	1.62	21.25	55.63	60.71	13.59
TJC	JF-I	R7 432	6.15	0.67	20.6	1.74	0.36	0.33	13.7	23	36	6.5	181.9	26.3	1.1	2.63	4.83	1.09	6.36	66.16	2.43
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	87.62	13.25
Potato	JF-III	R9 432	7.07	1.88	305.0	11.97	1.55	1.3	13.0	133	77	9.6	50.4	44	11.4	14.82	7.72	1.19	10.40	80.77	14.82

Interpretation:

Low Organic Matter
Low Potassium
Low Magnesium in some sites
Very low Phosphorous in Papaya site
Micronutrients S, Cu and Zn are deficient
Ca/Mg very low
A chili site has a very high Mg/K

Recommendations:

Applied Nitrogen as required by the Crop
Apply MOP
Apply MgSO4
Foliar application of micronutrients is very important

Kg/ Plot/ Application	Year 1-2	Year 3-5	Year 6+
Urea	0.17	0.25	0.34
MOP	0.31	0.47	0.63
$CaSO_4$	0.18	0.27	0.36
$MgSO_4$	0.39	0.59	0.78
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	50	50	50
Foliar Applications of micronutrients are required every two weeks, especially Cu and Zn			

Table 13: Fertigation Recommendations per Application and 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
TSP will addd P required in most locations
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/ Plot/ Application	Year 1-2	Year 3-5	Year 6+
Urea	0.51	0.85	0.83
MOP	0.47	0.79	0.39
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	50	55.7	50
Foliar Applications of micronutrients are required every two weeks, especially Cu and Zn			

Table 14: Fertigation Recommendations per Application and per Half Acre Plot

ANNEX 4: ESPALIER TRELLIS SYSTEM

ESPALLIER TRELLIS MANGO PRODUCTION SYSTEM

Totally Controls the Growth of the Tree to Make it Easier to Manage it

THE ESPALLIER TRELLIS PRODUCTION SYSTEM FOR MANGO IS MADE UP OF ONE DOMINANT CENTRAL TRUNK AND LATERAL BRANCHES TIED ALONG A WIRE WHICH IS SECURED TO WOODEN POSTS

Third Tier and Even Forth Tier Branches Are Allowed to Grow from Lateral Branches Along the Wire to Produce Fruit

FROM TIED LATERAL BRANCHES TERTIARY BRANCHES DEVELOP TO PRODUCE FRUIT

Less Biomass More Flowers and More Fruit

FIRST, 4"- 5" DIAMETER WOODEN POSTS ARE PLACED 6 METERS APART INSIDE MANGO TREE ROWS

Posts Should Be Placed 3 M Tall Above Ground and 0.5 M Below Ground

WIRE LINES, SPACED AT 0.5 M, ARE LAID OUT AND HELD BY THE POSTS TO FORM THE TRELLIS

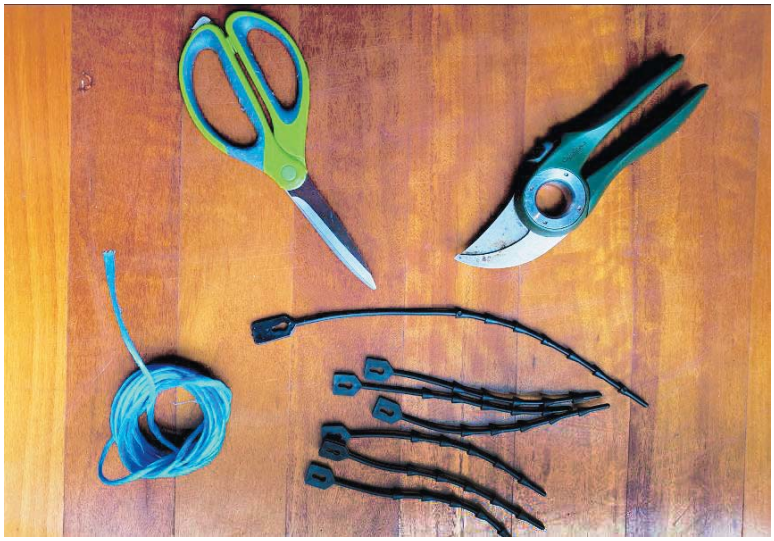
Wires Must Be Tensed Tightly to Be Able to Support Tree Branches

POST PLACEMENT CAN BE MECHANIZED

WIRES ARE TIGHTLY FIXED TO POSTS

The Wire Gauge Should Be at Least #14

TOOLS AND OTHER ACCESSORIES TO TIE MANGO BRANCHES TO TRELLIS



WATER SUCKERS AND VERY LOW BRANCHES ARE REMOVED BEFORE TRELLISING THE TREE

SMALL TREE MUST BE TALLER THAN FIRST WIRE ON THE TRELLIS

First Wire is 0.5 m High from the Ground Level

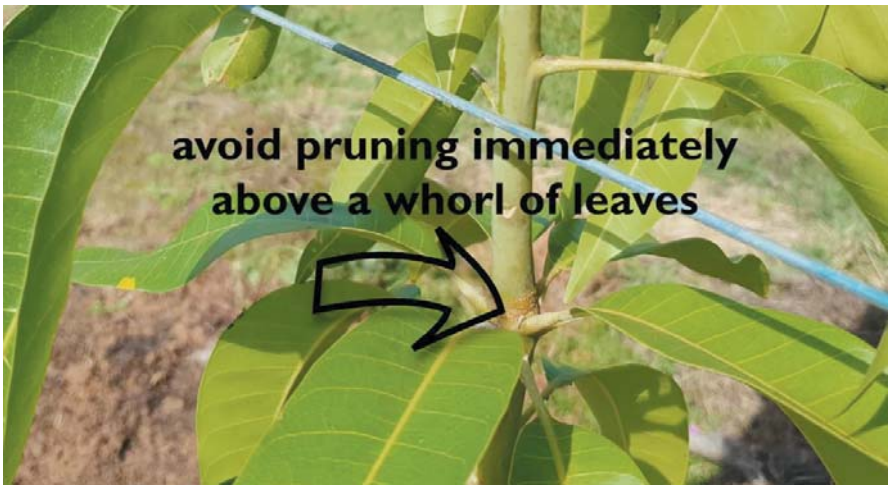
WHEN TREE HEIGHT IS AT LEAST 10 CM ABOVE NEXT WIRE, THE TOP IS CUT OR CLIPPED

At Least Three Leaf Whorls Must Remain Above the Wire

THE CUT FOR CLIPPING THE TREE TOP OFF MUST BE IN THE MIDDLE OF A LEAF NODE

Is Important to Clip the Tree at an Internode

ESPALLIER TRELLIS MANGO PRODUCTION SYSTEM



AVOID WORKING WITH NEW AND YOUNG BRANCHES DEVELOPED AFTER CLIPPING THE TREE OFF

ONCE THE NEW LATERAL SECONDARY BRANCHES ARE MATURED, THEY CAN BE BENT AND TIED TO THE WIRE

DO NOT TIE TOO TIGHTLY TO ALLOW THE LATERAL BRANCHES TO GROW IN DIAMETER

SECONDARY BRANCHES ARE TRAINED ALONG THE WIRE

PRUNE THE TIED LATERAL BRANCHES TO A LENGTH OF 15 CM - 20 CM TO PRODUCE TERTIARY BRANCHES

TIE THE TOP OF THE TREE TO THE NEXT WIRE TO TRAIN IT TO GROW STRAIGHT UP

THE TREE TOP MUST BE SECURED TO THE WIRE AFTER IT GROWS PAST THE WIRE

ONE OF THE TERTIARY BRANCHES DEVELOPED FROM PRUNING OF THE TIED SECONDARY BRANCHES MUST BE TIED ALONG THE WIRE TO EXTEND THE WIDTH OF THE TREE OVER THE WIRE

PRUNE OTHER TERTIARY BRANCHES TO ABOUT HALF THEIR LENGTH

CONTINUE PRUNING TERTIARY BRANCHES TO INDUCE TERMINAL BUDS THAT WILL FLOWER

Even Forth Tier Branches Can Be Allowed to Flower if They Are Well Positioned

A LADDER IS USED TO WORK ON HIGH TREES

CLOSE UP OF A WELL-DEVELOPED TREE ON THE ESPALLIER TRELLIS

MECHANIZED PRUNING OF ESPALLIER TRELLIS

After Harvesting the Trellised Mangoes, Mechanized Trimming Can Be Done to Cut Back Tertiary Branches in Preparation for the Next Harvest

MECHANIZED PRUNING CLOSE UP OF ESPALLIER TRELLIS MANGO

MANUAL PRUNING OF TERTIARY AND FOURTH TIER BRANCHES COMPLETES THE PREPARATION FOR THE NEXT HARVEST

CLOSE UP MANUAL PRUNING OF TERTIARY AND FORTH TIER BRANCHES ON ESPALLIER TRELLIS MANGO

FULL VEGETATIVE GROWTH OF MANGO ON ESPALLIER TRELLIS BEFORE FLOWERING

FRUITING OF ESPALLIER TRELLIS MANGO