MINISTRY OF AGRICULTURE, LIVESTOCK, LANDS AND IRRIGATION

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

Funded by
The European Union

ASMP
Agriculture Sector Modernization Project

OPERATIONAL MANUAL

PAPAYA

AGRICULTURE SECTOR MODERNIZATION PROJECT

A PARK
AGRICULTURE TECHNOLOGY DEMONSTRATION PARK

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

This publication was funded by the World Bank and European Union. Its contents are the sole responsibility of Agriculture Sector Modernization Project implemented under the Ministry of Agriculture Livestock, Lands and Irrigation and do not necessarily reflect the views of the World Bank or European Union.

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

The papaya, scientifically known as *Carica papaya*, is a tropical fruit with origins traced back to Central America and Southern Mexico. Believed to have been cultivated in the region for thousands of years, the papaya plant eventually spread to other tropical and subtropical areas around the world. The fruit-bearing tree belongs to the Caricaceae family and is characterized by its relatively short trunk and large, deeply lobed leaves.

The papaya fruit itself is a fleshy berry with a soft, orange or yellow-hued interior containing numerous black seeds encased in a gelatinous pulp. The plant is dioecious, meaning individual trees are either male or female, with only the latter producing the distinctive elongated and pear-shaped fruits. Renowned for its sweet taste, vibrant color, and rich nutritional profile, the papaya has become a popular and versatile fruit enjoyed in various culinary applications globally.

1.1 Optimal Ecological Requirements

Papaya (Carica papaya) is a tropical fruit that thrives in specific ecological conditions, making its cultivation highly dependent on warm climates and well-drained soils. Optimal ecological requirements for papaya growth include a temperature range between 70°F to 90°F (21°C to 32°C), with a preference for temperatures around 75°F to 85°F (24°C to 29°C). Papayas are sensitive to frost and require a frost-free environment for successful cultivation. The soil should be well-drained, rich in organic matter, and slightly acidic to neutral with a pH range of 5.5 to 7.0. Adequate sunlight is crucial, and papaya plants prefer full sun exposure to ensure optimal growth and fruit production. Additionally, consistent and evenly distributed rainfall or irrigation is essential, especially during the flowering and fruiting stages. Proper care in managing water levels, avoiding waterlogged conditions, and providing ample spacing between plants contribute to healthy papaya growth. Overall, the optimal ecological requirements for growing papaya involve a combination of warm temperatures, well-drained soil, sufficient sunlight, and appropriate water management.

2. LAND PREPARATION

2.1 Primary Land Preparation

1. Deep ploughing using a 60 cm diameter disk plough.
2. Incorporation of organic matter/ Compost by broadcasting 12 MT per hecta 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[1]

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[2]

Papaya is one of the most popular fruit plants grown in Sri Lanka. It is the most important fruit plant in the home gardens, and green papaya is also used as a vegetable. It is one of the few fruit plants which yields throughout the year, gives quick returns and can be grown under different soil and climatic conditions. Advanced papaya varieties or hybrids can yield 60-100 metric tons per hectare per year.

In Sri Lanka, the most common papaya is the Red Lady, a hybrid from Taiwan. Unfortunately, the Red Lady fruit is too large for the export market.

[1] It is unfortunate that Sri Lankan farmers do not have access to bigger tractors. It is recommended to procure modern machineries for Sri Lankan farmers, which can enable more efficient land preparation. ISP also recommends procuring moldboard plough to turn the soil over.

[2] According to DoA, the Tainung variety is not suitable for high density planting because it grows upto 3m. According to ISP, the height of the variety is not a factor that will preclude tall fruit trees from being planted in double row high density planting.

Practical examples are Ambul banana and TJC mango planted with high success by the ASMP in Sri Lanka. Tainung papaya responds the same way as Ambul banana to the positive geotropism created by the configuration of the ISP double row design, especially the width of the alley in between double rows. The plants lean towards the alley space making the harvest practice more efficient with regards to labour utilization. However, too much tree height, in any planting system or configuration, is not a desired variety attribute because it makes it difficult for the farmer to harvest the fruit and the tree is more susceptible to losses. The Tainung papaya procured by the Project is indeed an undesired tall variety. However, there are at least 5 cultivars of Tainung papaya that offer options on tree height (Annex 4)

The papaya fruit has a very sweet taste and aroma and is rich in vitamins A and C. As mentioned above, Papaya is also used as a vegetable, as well as in beverages, jams, cordial products, chewing gums, soaps, toothpaste, pharmaceuticals, and tanning. Papain from papaya is used as meat tenderizer.

The Tainung Papaya hybrid variety was selected by the ASMP for development in Sri Lanka for export purposes as fresh fruit. It was initially developed in Taiwan and is also known as Formosa papaya. This fruit is a cross between the Sunrise papaya and has gained popularity in many tropical regions worldwide. When ripe, the Tainung Papaya features pink-red flesh with a delicious and juicy flavor, and its green rind turns yellow.

The Tainung papaya tree, scientifically known as *Carica papaya* 'Tainung No. 2,' is a tropical and subtropical fruit tree that belongs to the Caricaceae family. This cultivar[3] is renowned for its robust growth, adaptability, and high fruit yield. The Tainung papaya tree typically reaches a height of 10 to 15 feet, although it can vary based on growing conditions and care. The trunk is single-stemmed, sturdy, and marked by a smooth, greenish-brown bark. The leaves are large, deeply lobed, and borne on long petioles.

The Tainung Papaya cultivar has 5 varieties of different tree heights. The choice of cultivar depends on factors such as available space, harvesting convenience, desired fruit size, and growth characteristics (Annex 4).

Tainung papayas are a large, oblong variety with yellow and green spotted skins. They have firm, salmon-colored flesh with a sweet flavor and mild aroma, and a central cavity full of small, round, shiny black seeds. They are sometimes also called Formosa papayas.

The Tainung papaya is distinguished by its hermaphrodite flowers, possessing both male and female reproductive organs within the same blossom. This unique feature allows the Tainung papaya to undergo self-pollination, a process where the pollen from the male parts of the flower fertilizes the female parts, leading to fruit development without the need for external pollinators. The hermaphroditic nature of its flowers enhances the plant's reproductive efficiency, ensuring a more reliable fruit set. This adaptation is particularly advantageous in areas with limited pollinator activity. The self-pollination capability of the Tainung papaya contributes to its reputation as a resilient and productive tropical fruit tree, offering a consistent harvest and demonstrating adaptability in various agricultural settings. In addition, Tainung hermaphroditic fruits are preferred in the international market (Annex 5).[4]

Despite of the excellent characteristics of the Tainung No. 2 papaya tree and fruit, this variety is susceptible to the devastating Papaya Ring Spot Virus (PRSV). However, papaya varieties resistant to the PRSV have been developed by transgenic means (Annex 6).

[3] Tainung papaya, even though is a hybrid, is also a cultivar of the papaya species. Cultivars result from breeding individuals to obtain a distinct trait i.e. Heirloom tomatoes. A hybrid is a breeding technique that crosses two different individuals to enhance their individual performance.

[4] One of the most important attributes of the Tainung papaya variety is that is self-pollinating. It does not need different sex flowers to produce a desired high-quality fruit. The flower has both sexes, and it pollinates itself. Tainung is well known around the world for the preponderance of hermaphroditic flowers. In fact, cultivars are now being bread to have a tree with mostly or only self-pollinating hermaphroditic flowers (Annex 5)

4. PLANTING MATERIAL

Planting material should be seedlings from seed purchased in the international and local market. The main stem height of the seedlings should be 15 cm to 20 cm, with Pencil thick diameter and having at least 3 green leaves and hard enough for field planting (Annex 1).

All planting material must be free from pests and diseases.

Farmers can make their own elevated nurseries to produce papaya seedlings; however, contracting a nursey with the capacity to supply the needs of the cluster would be a more practical way and the seedling quality would be more uniform (Annex 1).

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.

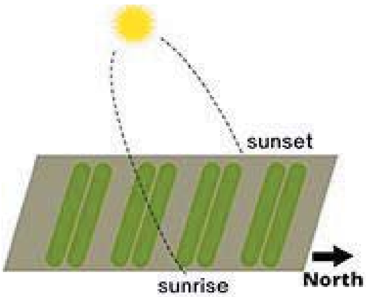


Figure 1: East to West orientation of rows

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 in 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 width 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.

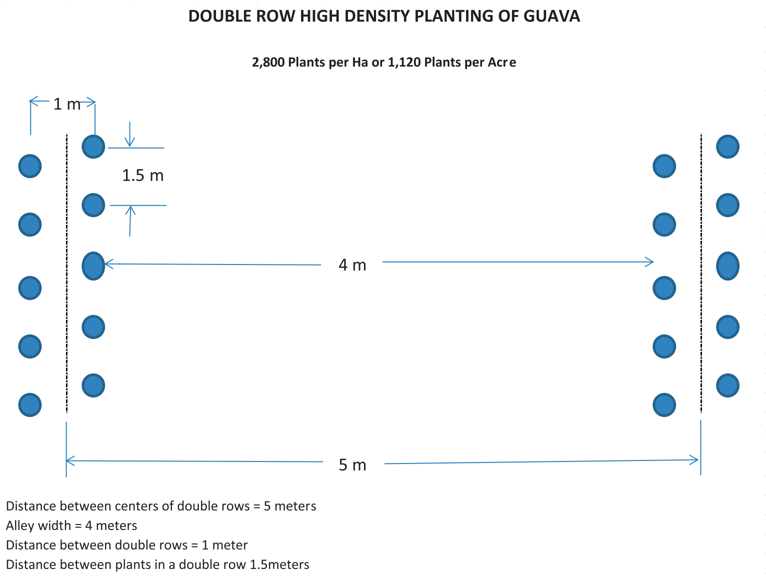


Figure 2: Double row high density planting

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 Papaya plant as required depending on rain fall.

5.2 Plant Spacings Within the Double Rows[5]

Papaya	1.50 m

5.3 Planting Aids

1. Construction twine (preferably white colored)
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 hole size 30 cm x 30 cm x 30 cm or one cubic foot

6. IRRIGATION AND FERTIGATION

6.1 Irrigation

Papaya requires 7 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 3: Micro-Sprinkler System

[5] According to DoA, Dwarf papaya varieties make it possible to grow Papaya under the High-density planting. The all-papaya varieties available in Sri Lanka are not suitable for high density planting. Therefore, the given spacing is not enough for Tainung papaya and it should be at least two meters.

According to ISP, the spacing of 1.5 m within the double row with a width of 1 m has been used successfully to grow tall papa ya trees such as the Piola variety in Malaysia and the Tainung variety in Samoa in the Pacific islands. As mentioned above, the height attribute of a variety does not preclude a tree from a tall variety from being planted in a double row high density system or configuration as recommended by the ISP. In addition, there is no field experience in Sri Lanka to indicate that a 2 m spacing is better than a 1.5 m spacing. There is also no proof that a width of 1.5 m of the double row is better than a width of 1 m. This is only speculation.

The configuration of the high-density double row planting with a width of the double row of 1.5 m is not ISP technology at all. This modification made to original ISP technology was made arbitrarily by the Project without the non-objection by the ISP.

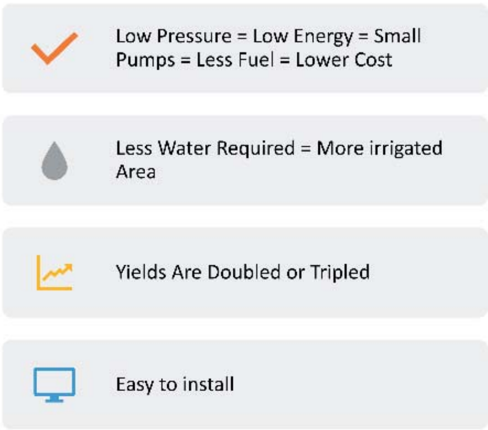


Figure 4: Advantages of low-pressure irrigation

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

6.2 New Irrigation Concepts

- 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 Papaya consumptive water use of 7 mm of water per day is equivalent to 49 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 Papaya using the micro sprinkler system:

Table 1: Irrigation Schedule

Irrigation Schedule	1-3 months		4-12 months		One Year +	
Irrigation Time (Hours/ Minutes)	1	56	1	18	1	41

6.4 Fertigation

The Tainung papaya requires a balanced supply of essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and micronutrients. The N-P-K ratio is typically around 8-6-6 for papaya.

1. **Nitrogen (N):** Papayas have a high demand for nitrogen, especially during the vegetative growth stage. However, excessive nitrogen can lead to vegetative growth at the expense of fruiting. A balanced fertilizer with a higher nitrogen content during the early stages can be beneficial.
2. **Phosphorus (P):** Phosphorus is essential for root development and flowering. A balanced fertilizer with a higher phosphorus content during flowering and fruiting stages is recommended.
3. **Potassium (K):** Potassium is important for fruit development and overall plant health. Adequate potassium helps in preventing diseases and improving fruit quality.
4. **Magnesium (Mg):** Papayas benefit from magnesium, especially in acidic soils. If soil tests indicate a magnesium deficiency, consider applying magnesium-containing fertilizers.[6]

[6] Magnesium is not recommended as a nutrient by the ISP. It is recommended as a soil amendment to improve the chemistry of the soil cation exchange complex and make the soil more fertile and productive. Small supplemental quantities of Mg from 50 Kg/Ha to 100 Kg/Ha (0.21 meq to 0.42 meq of the Mg^{2+} ion) are recommended. Because the concentration of Mg in fertilizer grade $MgSO4$ is only 10%, a large application of the fertilizer is required to supply to the soil with a low amount of the Mg^{2+} ion.

5. **Micronutrients:** Tainung papaya, like otheBr crops, requires trace elements or micronutrients. These include iron, manganese, zinc, copper, boron, and molybdenum. Micronutrient deficiencies can be addressed through the application of micronutrient fertilizers or organic amendments. Consider foliar applications if deficiencies are observed.
6. **Boron:** This minor element or nutrient is of significance for papaya production in Sri Lanka (see Annex 7).

The fertilizer application is based on soil test results. The soil analysis report was interpreted using critical levels of nutrients for papaya in the soil and critical cation ratios to determine the cation balance of the soil. Annex 3 shows the soil analysis reports for the ASMP papaya Clusters in Mullaitivu and Polonnaruwa.

The results for the Mullaitivu Papaya Cluster area soil tests indicated the following:

Low Organic Matter and Potassium
Deficient Phosphorus and Micronutrients (S, Cu, Zn)
Unbalanced Cation Ratios against Mg

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

Urea, TSP, MOP and $MgSO_4$ - Magnesium Sulphate (Supplement as soil amendment)
Foliar fertilization with micronutrients
Phosphoric acid for irrigation system

Based on the above considerations, the amount of nutrients to be applied is in elemental and oxide form:

Recommendation	N	P	K	Mg
Kg/ Ha	250	100	250	75
Lb/ acre	250	100	250	75
Kg/ acre	113.6	45.5	113.6	34.1

Table 2: Nutrition Quantities

Phosphoric Acid P (Kg/ Ha)	20.0			
Recommendation	**Urea**	**P_2O_5**	**K_2O**	**MgO**
Kg/ Ha	543.5	229.1	301.3	47.7
Lb/ acre	543.5	229.1	301.3	47.7
Kg/ acre	247	104.1	136.9	21.7

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

Kg/ Acre	Urea	P Acid	TSP	MOP	MgS_2O_4
Fertilizer per year (Season)	247	33	231	228	341

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

Considering the stage of development of the crop, the quantities of fertilizer materials required per season

Ratio Based on Tree Age	1 to 4 Months	4 to 7 Months	One Year +
Urea	123.5	247.0	370.6
P Acid	16.3	32.7	49.0
TSP	115.7	231.4	347.1
MOP	114.1	228.2	342.4
$MgSO_4$	170.5	340.9	511.4

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

Kg/Acre	1 to 4 Months	4 to 7 Months	One Year +
Urea	4.75	9.50	14.25
P Acid	0.63	1.26	1.89
TSP	4.45	8.90	13.35
MOP	4.39	8.78	13.17
$MgSO_4$	6.56	13.11	19.37

Table 5: Week-wise, fertilizer quantities

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

Kg/Acre/Week	Year 1	Year 2	Year 3+
Urea	2.375	4.751	7.126
P Acid	0.314	0.629	0.943
TSP	2.225	4.450	6.675
MOP	2.195	4.389	6.584
$MgSO_4$	3.278	6.556	9.834

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

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

Kg/Acre/Application	Year 1	Year 2	Year 3+
Urea	0.26	0.52	0.78
TSP	0.24	0.49	0.73
MOP	0.24	0.48	0.72
$MgSO_4$	0.36	0.72	1.08
Applications per week	2		
P Acid Application every two weeks (ml)	50	50	61.5
Foliar Applications of Micronutrients every two weeks			

Table 7: Fertigation Recommendations per Application per Half Acre Plot

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 Papaya 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

8.1 Papaya Ring Spot Virus (PRSV)

The Papaya Ring Spot Virus (PRSV) is a plant pathogenic virus that specifically affects papaya plants (*Carica papaya*). This virus poses a significant threat to papaya cultivation, causing severe economic losses in affected regions. PRSV belongs to the Potyviridae family and is transmitted primarily by aphids in a non-persistent manner.

Symptoms:

The symptoms of PRSV infection vary but commonly include distinctive ringspots on the leaves, which give the virus its name. Infected plants may exhibit stunted growth, reduced fruit size, and deformation. In severe cases, PRSV can lead to complete crop loss, impacting the livelihoods of farmers dependent on papaya cultivation.

Transmission:

Aphids serve as the primary vector for PRSV transmission. The virus can also spread through mechanical means, such as contaminated tools or hands during cultivation practices. Additionally, the movement of infected plant material, including seeds and seedlings, contributes to the spread of the virus across regions.

Geographical Distribution:

PRSV is widespread in tropical and subtropical regions, where papaya cultivation is prevalent. The virus has been reported in various countries, including those in Asia, Africa, and the Americas. The global distribution of PRSV underscores the importance of effective control measures to mitigate its impact on papaya production.

Control Strategies:

Several strategies are employed to manage and control PRSV:

a. Resistant Varieties: Developing and cultivating papaya varieties resistant to PRSV is a key approach to controlling the virus. Resistant cultivars have been developed through breeding programs using transgenic techniques to enhance the crop's resilience. The University of Hawaii has released two resistant varieties, Solo Sunrise and Solo Sunset.
b. Vector Control: Managing aphid populations using insecticides or other environmentally friendly methods helps reduce the transmission of PRSV. Integrated pest management practices are crucial for sustainable control. When chemical control is practiced as recommended, only pesticides that are registered in Sri Lanka should be used at DOA recommended amounts.
c. Quarantine Measures: Implementing strict quarantine measures to prevent the movement of infected plant material, including seeds and seedlings, can help contain the spread of the virus to new areas.
d. Farm Hygiene Practices: Adoption of good agricultural practices, including proper sanitation and hygiene, reduces the risk of mechanical transmission. Regular inspection and removal of infected plants are essential to prevent the further spread of the virus.

The papaya Ring Spot Virus remains a significant challenge for papaya growers worldwide. Effective control measures involve a combination of breeding efforts, vector management, and good agricultural practices. Ongoing research and collaboration among scientists, farmers, and policymakers are crucial for developing sustainable strategies to mitigate the impact of PRSV on papaya cultivation.

8.2 Phytophthora Disease

Phytophthora disease, caused by the oomycete pathogen *Phytophthora palmivora*, is a significant threat to papaya cultivation worldwide. This destructive disease affects various parts of the papaya plant, leading to severe economic losses in affected regions.

Symptoms:

a. Root Rot: Phytophthora infection often initiates in the roots, causing rotting and decay. Infected roots appear dark, water-soaked, and may exhibit a foul odor. This compromises the plant's ability to absorb nutrients and water, resulting in stunted growth.
b. Crown Rot: As the infection progresses, it can extend to the crown of the papaya plant. This leads to the wilting and yellowing of leaves, ultimately causing the death of the entire plant.
c. Fruit Rot: The pathogen can also infect papaya fruits, causing them to develop dark lesions and rot. Infected fruits become unsuitable for consumption, leading to significant economic losses for farmers.

Spread and Transmission:

Phytophthora disease spreads through contaminated soil, water, and plant debris. The pathogen can persist in the soil for extended periods, making it challenging to manage and control. Additionally, waterlogged conditions and high humidity create favorable environments for disease development and spread.

Management and Control:

1. Resistant Varieties: Planting resistant papaya varieties is an effective strategy to minimize the impact of Phytophthora disease. Researchers and breeders are actively working on developing papaya cultivars with increased resistance to the pathogen.
2. Sanitation: Proper sanitation practices, including the removal and destruction of infected plant material, can help reduce the inoculum in the field.
3. Fungicide Application: Fungicides can be used to manage Phytophthora disease, but their efficacy may vary. Timely and strategic application of fungicides, as per recommended guidelines, can help control the spread of the pathogen. When chemical control is practiced as recommended, only pesticides that are registered in Sri Lanka should be used at DOA recommended amounts.
4. Crop Rotation: Implementing crop rotation with non-host plants can disrupt the disease cycle and reduce the likelihood of Phytophthora infection in subsequent papaya crops.

Phytophthora disease poses a serious threat to papaya cultivation, impacting both plant health and fruit quality. Effective management strategies involve a combination of cultural practices, the use of resistant varieties, and judicious application of fungicides. Ongoing research is crucial to developing sustainable and integrated approaches for the prevention and control of Phytophthora disease in papaya cultivation.

8.3 Mealy Bugs

Paracoccus marginatus

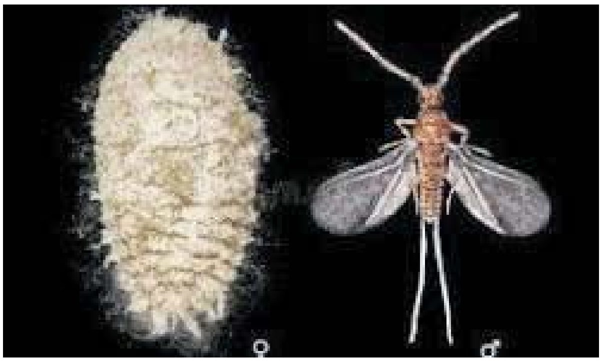
The papaya mealybug (Paracoccus marginatus) is an invasive insect pest that has caused significant agricultural damage in tropical and subtropical regions around the world. Originally from Central America, this pest has spread to various parts of Asia, Africa, and the Pacific, affecting a wide range of host plants, particularly papaya. The papaya mealybug can lead to considerable economic losses due to reduced crop yields and quality. Understanding its life cycle, preventive measures, and control strategies is crucial for effective management.

Life Cycle

The life cycle of the papaya mealybug consists of several stages: egg, nymph, and adult.

1. Egg Stage: Female papaya mealybugs lay their eggs in cottony, waxy masses on the surfaces of host plants. Each female can lay between 150 to 600 eggs over her lifetime. The eggs are elliptical, initially translucent, and turn yellow as they mature. The incubation period lasts between 3 to 9 days, depending on environmental conditions.

2. Nymph Stage: After hatching, the nymphs, also known as crawlers, emerge and move around to find suitable feeding sites. The nymph stage has three instars for females and four for males. Nymphs are yellowish with a waxy coating that gives them a white appearance. This stage lasts for about 2 to 3 weeks, during which the nymphs feed on plant sap, causing damage.



3. Adult Stage: Adult females are wingless, about 2 to 3 mm in length, and covered with a white, waxy secretion. Males, on the other hand, are smaller, with a single pair of wings, and do not feed. The adult stage for females lasts about 30 days, while males live only a few days. Females can reproduce parthenogenetically, meaning they do not require males to produce offspring.

Damage

Damage from mealy bugs can be severe for papayas if proper measures are not taken:

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

Preventive Measures

Preventing the spread and establishment of papaya mealybugs involves several key strategies:

1. Quarantine and Inspection: Implementing strict quarantine measures and inspecting plants before transport can prevent the introduction of the pest to new areas. This includes inspecting nursery stock, fruits, and other plant materials.
2. Sanitation: Maintaining clean cultivation practices, such as removing infested plant parts and disposing of them properly, can reduce the likelihood of mealybug infestations. Regularly cleaning equipment and tools used in the field can also help.
3. Host Plant Resistance: Developing and planting resistant varieties of papaya and other susceptible crops can minimize damage. Ongoing research into breeding resistant plant varieties is essential.

Control Strategies

Once an infestation has been identified, various control strategies can be employed to manage the papaya mealybug population:

1. Biological Control: One of the most effective and environmentally friendly methods is using natural enemies to control mealybug populations. Predators such as lady beetles (Cryptolaemus montrouzieri) and parasitoids like the wasp (Acerophagus papayae) have been successfully used in many regions.
2. Chemical Control: Insecticides can be used to manage severe infestations, but they should be applied judiciously to avoid harming beneficial insects and developing resistance. Insect growth regulators and systemic insecticides are often recommended. When chemical control is practiced as recommended, only pesticides that are registered in Sri Lanka should be used at DOA recommended amounts.
3. Cultural Practices: Implementing good cultural practices such as crop rotation, intercropping, and maintaining plant health through proper fertilization and irrigation can reduce the susceptibility of plants to mealybug attacks. In addition:
    a. Attempt to dislodge mealybugs from affected plant parts by hosing them off with soapy water applied with a hose with pressure.
    b. Remove and destroy affected parts of the plant at the beginning of the infestation.
    c. Heavily infested branches may be pruned to control the pest, especially on the tender branches before flowering begins.
    d. Conserve natural enemies.
    e. Insecticides do not generally provide adequate control of mealybugs owing to their wax coating.
    f. Destroy ant nests inside the plantation or in proximity.
4. Integrated Pest Management (IPM): An IPM approach combines biological, chemical, and cultural practices to manage pest populations in an economically and ecologically sustainable way. Regular monitoring and the use of pheromone traps can help in early detection and timely intervention.

The papaya mealybug is a formidable pest that poses a significant threat to agriculture in tropical and subtropical regions. Understanding its life cycle is crucial for developing effective management strategies. Preventive measures such as quarantine, sanitation, and host plant resistance can help prevent infestations. Once established, control strategies including biological control, chemical applications, cultural practices, and integrated pest management are essential to mitigate the impact of this pest. Continued research and collaboration among scientists, farmers, and policymakers are vital to ensure sustainable and effective management of the papaya mealybug.

8.4 Papaya Fruit Fly

Bactrocera dorsalis

The most common fruit fly species that attacks papaya in Sri Lanka is, commonly known as the Oriental fruit fly. This species, belonging to the family Tephritidae, poses a significant threat to papaya production. The Oriental fruit fly has a yellowish-brown body with distinctive black spots on its wings. The life cycle of this fruit fly consists of four stages: egg, larva, pupa, and adult. The female lays eggs in ripening or ripe papaya fruits, and upon hatching, the larvae feed on the pulp, causing damage and rendering the fruit unmarketable. The infested fruits may exhibit premature ripening, rotting, and are susceptible to secondary infections.

Control measures for Oriental fruit fly infestations in papaya orchards include cultural, biological, and chemical methods. Cultural practices involve proper orchard sanitation, prompt removal and destruction of infested fruits, and the use of bagging techniques to physically protect fruits from fruit flies. Biological control agents, such as parasitic wasps (e.g., Fopius arisanus) and entomopathogenic nematodes (e.g., Steinernema spp.), can be utilized to target fruit fly populations. As for chemical control, insecticides are employed as a last resort. It is advisable to consult local agricultural authorities, research institutions, or extension services in Sri Lanka for the most up-to-date and region-specific information on pesticide recommendations and quantities. When chemical control is practiced as recommended, only pesticides that are registered in Sri Lanka should be used at DOA recommended amounts.

The Papaya Fruit Fly poses a significant threat to papaya cultivation, affecting fruit quality and marketability. Integrated pest management (IPM) practices, including a combination of cultural, biological, and chemical control measures, are essential for effective management. Continuous monitoring and collaboration between researchers, farmers, and agricultural extension services are critical to developing sustainable strategies to combat the Papaya Fruit Fly and minimize its impact on papaya crops.

8.5 Anthracnose

Anthracnose is a common fungal disease that affects a variety of plants, including papaya.

Symptoms:

Anthracnose in papaya fruit is primarily caused by the fungus *Colletotrichum gloeosporioides*. The symptoms typically manifest as small, dark, sunken lesions on the fruit's surface. As the infection progresses, these lesions may enlarge and coalesce, leading to extensive fruit rot. The affected areas often produce spore masses, giving the lesions a distinctive appearance.

Causes:

Several factors contribute to the development and spread of Anthracnose in papaya fruit. These include:

1. Environmental Conditions: Warm and humid climates provide favorable conditions for fungal growth, increasing the risk of Anthracnose development.
2. Injury to Fruit: Wounds or injuries on the papaya fruit surface create entry points for the Anthracnose fungus. These injuries can be caused by insects, abrasions, or improper harvesting techniques.
3. Poor Cultural Practices: Practices such as over-irrigation, inadequate spacing between plants, and improper sanitation in the orchard can create an environment conducive to Anthracnose.

Management Strategies:

Effective management of Anthracnose in papaya fruit involves a combination of cultural, biological, and chemical control methods. Some recommended strategies include:

1. Cultural Practices: Maintain proper orchard hygiene by removing and destroying infected fruit. Prune and thin plants to improve air circulation, reducing humidity levels. Adequate spacing between plants can also help minimize the spread of the disease.
2. Fungicide Application: Use fungicides containing active ingredients like azoxystrobin or mancozeb. Application timing and frequency should be based on the severity of the disease and the specific recommendations of agricultural extension services. When chemical control is practiced as recommended, only pesticides that are registered in Sri Lanka should be used at DOA recommended amounts.
3. Resistant Varieties: Selecting papaya varieties with natural resistance to Anthracnose can be an effective preventive measure.
4. Post-Harvest Management: Implement proper post-harvest handling practices to minimize injuries to the fruit and prevent the spread of the fungus during storage and transportation.

The selection and proper use of fungicides are crucial components of an integrated approach to Anthracnose management in papaya. It is essential for farmers to consider factors such as the specific stage of crop development, resistance management, and environmental impact when choosing and applying fungicides. Regular monitoring, adherence to recommended application schedules, and the incorporation of cultural practices contribute to a comprehensive strategy for Anthracnose control in papaya cultivation.

Anthracnose poses a significant threat to papaya fruit production, impacting both quality and yield. A holistic approach that combines cultural practices, fungicide application, and the use of resistant varieties is essential for effectively managing and mitigating the impact of Anthracnose on papaya crops.

9. INTERCROPPING

- The double row and high-density planting system is very well suited for intercrops with the papaya trees in the 4 m alley between double rows.
- Intercropping is always possible during the life of the plantation as long the coverage of the canopy of the papaya tree does not affects the growth and development of the intercrop by shading.
- Intercrops of annual crops, such as onions or chili, could be used for better utilization of land and as an additional source of income for the farmers and as a weed control strategy.
- Intercropping with crops that share common pests and diseases must be avoided. The use of chemicals that can harm the papaya tree and the fruit must be avoided as well in intercropping.

10. HARVESTING

Papaya (Carica papaya) is a popular tropical fruit known for its sweet flavor and nutritional benefits. Harvesting papayas at the right time and using proper techniques is crucial to ensure fruit quality and overall yield.

10.1 Harvesting Time

Papayas are typically ready for harvesting when the skin of the fruit develops a slightly yellowish hue and yields to gentle pressure. The time from flowering to fruit maturity is usually around 4 to 5 months, but this can vary based on the papaya variety and growing conditions. It's essential to monitor the fruit closely to determine the optimal harvest time.

10.2 Harvesting Techniques

1. Tools: For harvesting papayas, a sharp knife or pruning shears should be used to cut the fruit from the tree. Clean and well-maintained tools are essential to prevent damage to the fruit and the tree.
2. Fruit Inspection: Before harvesting, visually inspect the papayas to ensure they have reached the desired size, color, and firmness. Avoid harvesting overly mature or underdeveloped fruits.
3. Cutting Technique: When cutting the papayas from the tree, leave a short piece of the stem attached to the fruit. This stem portion, known as the "handle," can help in handling and transporting the fruit without causing damage.
4. Handling: Handle the harvested papayas with care to prevent bruising or skin damage, as these can lead to spoilage during storage and transportation.

Effective papaya harvesting involves proper timing, careful inspection, and gentle handling to ensure high-quality fruit.

11. POST-HARVEST HANDLING

Post-harvest quality of papayas is influenced by factors such as maturity at harvest, handling practices, temperature management, and control of ethylene exposure. Quality parameters include color, texture, flavor, and freedom from defects such as bruising, sunburn, or chilling injury.

11.1 Papaya Postharvest Facts

- Papaya is a climacteric fruit, meaning they continue to ripen after harvest.
- The optimal temperature for storing Papaya is between 10°C -12°C (50°F -54°F). More mature or ready to eat Papaya can be stored at 10°C (50°F).
- Papaya is sensitive to chilling injury, which can occur when they are stored at temperatures below 7°C (44.6°F).
- The ideal relative humidity for storing Papaya is between 85% and 95%.
- Papaya produces ethylene gas, which can cause them to ripen more quickly. it's best to store Papaya separately from other fruits and vegetables sensitive to ethylene.
- Papayas can be ripen following a protocol similar to bananas using an ethylene gas generator.

11.2 Papaya Product Specifications

Papayas intended for export are carefully graded by size and stage of ripeness. The fruit should be uniform in size and ripeness and be free from bruises, blemishes, and insect damage. Most importers also require that papayas be green with yellow spots and have a uniform softness; a smooth, unblemished skin; and a minimum sugar content of 12.

Effective post-harvest management of papayas is essential for preserving their quality and extending shelf life. Proper handling, storage, and ripening practices are crucial in ensuring that consumers receive papayas of the highest quality.

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

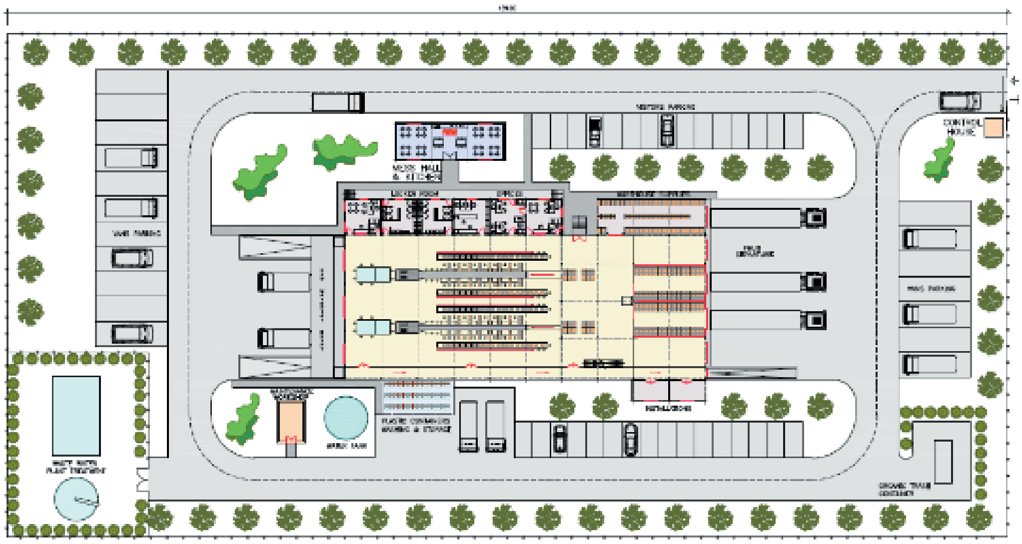
- Export Containers - Corrugated cardboard boxes containing 13 to 15 Kg net of fruit on arrival.
- Shipping fruit weight – 13.3 Kg to 15.3 Kg.
- Maturity Stage – Mature green to mature with yellowing showing depending on voyage time to market.
- Maturity Tolerance – 5% to 10% by weight (1 to 2 Papaya fruits per box).
- Sanitary and Phytosanitary Condition – Fresh and free from blemishes, diseases, and pests.

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

Size	Papaya Weight (gm)	Count per Box
X-Large	1.6 -1.9	8
Large	1.4 – 1,7	9
Medium	1.3 – 1.5	10
Small	1.00 – 1.25	12

Based on Shipping Weight of 13.3 Kg to 15.3 Kg

11.3 Packing Centre Layout



11.4 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

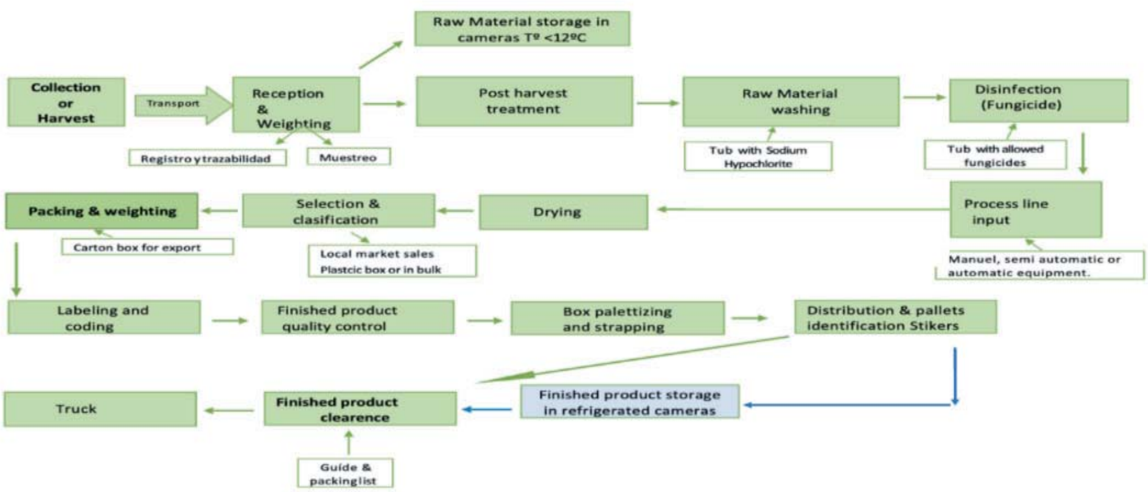


Table 8: Post Harvest Fruit Treatment Flow Diagram

Papayas 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.

Papayas can either be offloaded to the packinghouse in field crates or from trucks with large cargo holds. Upon arrival at the packinghouse, Papayas are transferred into a water tank for cleaning. In the tank, they are 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 Papaya 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 Papayas that are misshaped, bruised, cut, or have signs of decay. Papayas are packed into ventilated, single-layer cartons with or without lids. The openings in the cartons are used for ventilation and are important to ensure uniform temperature and humidity during storage and shipping.

11.5 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.

11.6 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

11.7 Packing Tips

- For the export market, pack Tainung papayas in single layer in fibreboard cartons of 13.3 kg – 15.3 kg weight.
- The fruits per carton range from 8 – 12.
- 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 Papayas 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.

11.8 Packing House Sanitation

Fresh produce such as Papaya 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 5: Packaging House Sanitation

11.9 Storage Tips

- Mature Papayas are sensitive to chilling injury. There is impaired ripening resulting in poor colour and flavour development at low temperature (7 °C).
- Relative Humidity should be maintained at between 85 % – 90 %).
- Papayas 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 Papayas that consumers prefer.

12. EXPORT PROTOCOL

12.1 Papaya Shipping Reefer Containers

Papayas are shipped in reefer containers (refrigerated). These containers provide refrigeration to protect the quality and prolong the shelf life of the produce. The quantity of 5 kg Papaya 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	1,680	20	1,540	1,848

BB = Break Bulk

Pallet configuration is 7 x 10 for a normal reefer and 7 x 11 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 Papaya. There is usually an upfront charge for palletized fruit to offset the cost.

The temperature for holding and shipping Papaya ranges from 8 ^{o}C to 10 ^{o}C depending on the internal maturity of the fruit and under normal atmosphere conditions. For controlled atmosphere shipping, the temperature could be 10 ^{o}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 longer 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 6: Reefer Container

Figure 7: Reefer Container Settings Panel

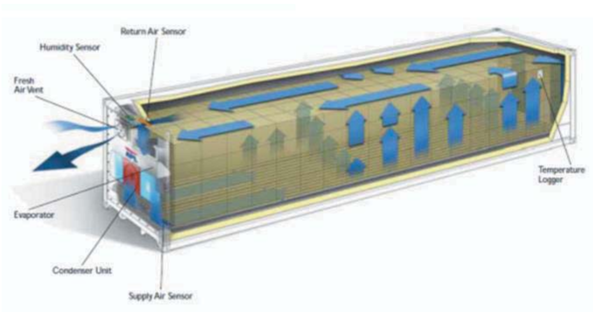


Figure 8: Reefer Container Cool Air Flow

Figure 9: Temperature Monitoring Device

Figure 10: Loading Papaya in Reefer Container

12.2 Mixed Papaya Containers

Shipping volumes of Papaya such as Apple Papaya 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 Papaya in Sri Lanka on a weekly basis.

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

13. COST BENEFIT ANALYSIS

Table 9: Farmer Level Cost Benefit Analysis[7]

Item	Unit	Without project	With Project
Fresh Production /HA	MT	84.2	112.5
Production Waste	%	15	15
Sales Volume/HA	MT	71.6	95.6
Cost of Production/HA	LKR	1,639,868	2,259,153
Cost/Kg	LKR	22.9	23.6
Selling Price/Kg	LKR	85	109
Gross Income/ HA	LKR	6,085,401	10,420,400
Gross Margin/ HA	LKR	4,445,533	8,161,247
Benefit/Cost Ratio		**2.7**	**3.6**

[7] Yield for the cost benefit analysis is given at 112.5 mt/Ha in the manual. This yield is based on a population density of 2,800 papaya trees per hectare, on a fruit weight of 1.5 Kg, 33 papayas per tree per year and a marketable portion of 80% of the gross yield. Papaya plants typically produce a varying number of fruits per plant based on factors such as age, variety, growing conditions, and agricultural practices. On average, a healthy papaya plant can yield anywhere from 30 to 100 fruits per year, with some productive plants even producing up to 200 fruits annually. The average weight of a papaya fruit varies depending on the variety and stage of ripeness but generally ranges from 1 to 5 pounds. The weight can even go higher for some larger varieties. These figures serve as rough estimates, and actual yields and fruit weights may vary. (Source: "Papaya Production Guidelines" by the University of Florida, IFAS Extension)

ANNEX 1: SPECIFICATION FOR PAPAYA PLANTING MATERIAL

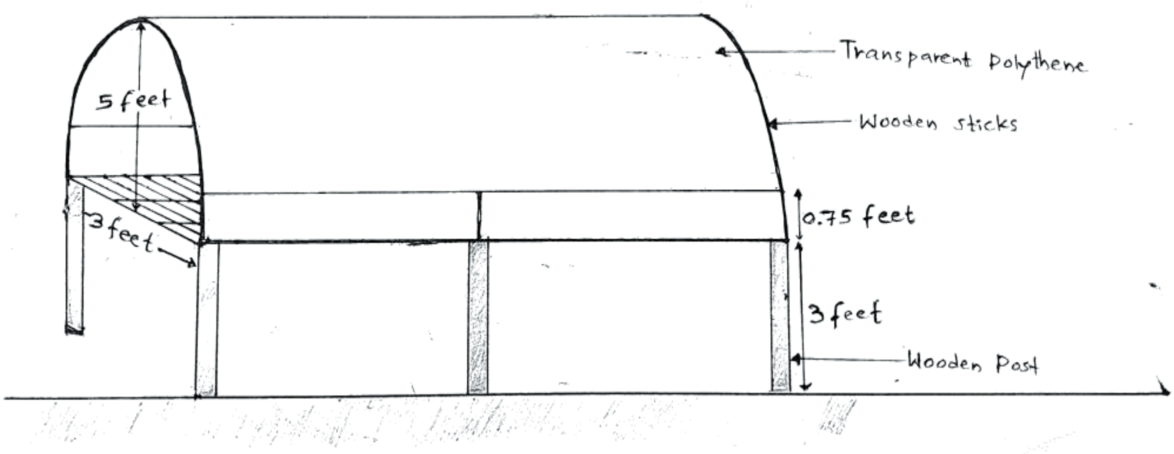
Supplier

1. Supplier should own a DOA SCS registered nursery.
2. Supplier should transport the plants to the site directed by the ASMP.
3. Supplier should submit a certificate from a reputed laboratory to prove that plants are free from pests and diseases.
4. Preference should be given to suppliers within the district to minimize physical damages in transportation as well as to minimize transportation cost.

Seedlings

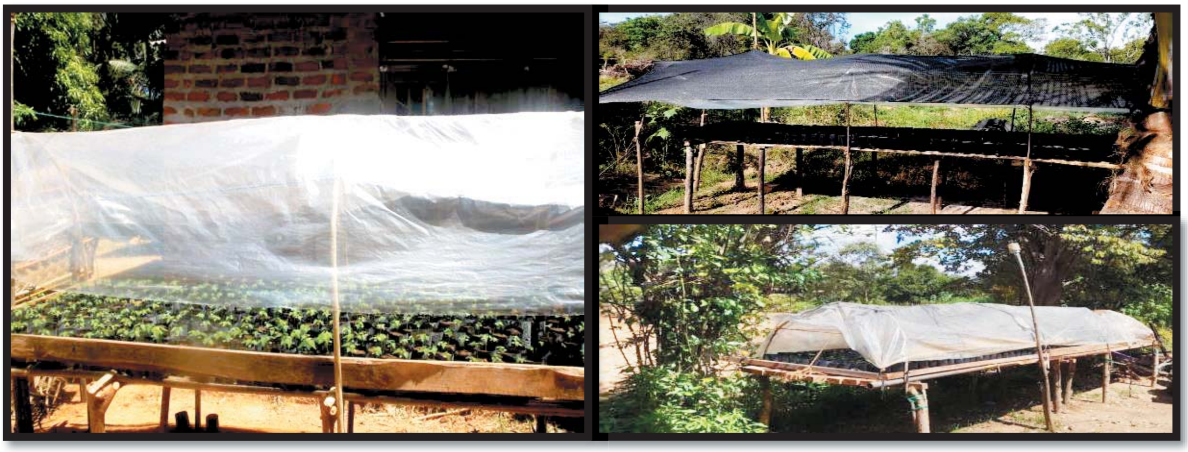
1. Seedlings must be grown in black color Polyethylene bags. The size of bags should measure as diameter 12.5 cm and height 20 cm.
2. Bags must be filled with compost mixture as the potting media.
3. Plants should be placed in the center of the bag to allow for a well-developed root system.
4. Seed should be obtained from reputable suppliers of imported seeds.
5. Main stem height of the plant should be 15 cm to 20 cm, with Pencil thick diameter and having at least 3 green leaves and hard enough for field planting.
6. The plant must reflect the characters of the variety.

Elevated Nurseries



- For 650 seedlings
- Nursery trays – 15 trays (45 holes)
- Polythene bags - 650 bags (4 by 5 inches)
- Height - 2.5 - 3 feet

- Length - 15 feet
- Width - 3 feet



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

Papaya Cluster - Polonnaruwa
Analitical Report on Soil

Sample Code	Lab No	pH	OM	EC	Ca	Mg	K	NH4-N	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Ca/K	Mg/K	Ca+Mg/K	Ca Sat.
		1:2.5, H2O	%	µs/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/kg					
243 - Ihalawewa	B7 470	7.19	1.34	72.5	8.4	2.35	1.47	90.4	38	19	4.9	570	254	9.1	12.22	3.57	5.71	1.60	7.31	68.74
Dulantha Medawala	B8 470	6.57	1.75	74.1	8.95	3.14	1.26	59.3	65	19	9.1	328	86	34	13.55	2.85	7.10	2.49	9.60	66.05
279 - Magulpokuna	B9 470	6.51	1.48	57.8	10.03	3.34	0.38	37.8	25	18	19.6	328	122	2.6	13.95	3.00	26.39	8.79	35.18	71.90
219 - Bandanagala	B10 470	6.4	1.34	53.3	5.6	1.48	0.53	59.6	22	21	2.8	426	96	3.2	7.37	3.78	10.57	2.79	13.36	75.98
S. M. Wasantha Samarakoon	R1 471	6.52	0.94	60.7	4.31	1.88	0.83	52	20	26	2.7	592	72	3.6	7.22	2.29	5.19	2.27	7.46	59.70
Pihitiwewa Unit 223 - Pahalayakkure	R2 471	5.71	2.15	114.6	9.69	3.19	1.4	38.2	434	33	10.4	412	110	16	14.68	3.04	6.92	2.28	9.20	66.01

Interpretation:
- Low Organic Matter
- Low Potassium in 3 areas
- Low Sulpher, Copper and Zinc
- Ca/Mg narrow
- Ca/K also narrow

Recommendations:
- Apply Nitrogen as required by the crop
- Apply MOP in 3 areas
- Apply Sulpher
- Apply Copper in 4 areas
- Apply Zinc in 4 areas

Kg/ Plot/ Application	Initial	Mid	Late
Urea	0.26	0.52	0.78
TSP	0.24	0.49	0.73
MOP	0.24	0.48	0.72
MgS_2O_4	0.36	0.72	10.08
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	50.0	50.0	61.5
Foliar Applications of Micronutrients every Week			

Table 10: Fertigation Recommendations per Application per Half Acre Plot

Papaya Cluster - Polonnaruwa
Analitical Report on Soil

Sample Code	Lab No	pH	OM	EC	Ca	Mg	K	NH4-N	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Ca/K	Mg/K	Ca+Mg/K	Ca Sat.
		1:2.5, H2O	%	µs/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/kg					
243 - Ihalawewa	B7 470	7.19	1.34	72.5	8.4	2.35	1.47	90.4	38	19	4.9	570	254	9.1	12.22	3.57	5.71	1.60	7.31	68.74
Dulantha Medawala	B8 470	6.57	1.75	74.1	8.95	3.14	1.26	59.3	65	19	9.1	328	86	34	13.55	2.85	7.10	2.49	9.60	66.05
279 - Magulpokuna	B9 470	6.51	1.48	57.8	10.03	3.34	0.38	37.8	25	18	19.6	328	122	2.6	13.95	3.00	26.39	8.79	35.18	71.90
219 - Bandanagala	B10 470	6.4	1.34	53.3	5.6	1.48	0.53	59.6	22	21	2.8	426	96	3.2	7.37	3.78	10.57	2.79	13.36	75.98
S. M. Wasantha Samarakoon	R1 471	6.52	0.94	60.7	4.31	1.88	0.83	52	20	26	2.7	592	72	3.6	7.22	2.29	5.19	2.27	7.46	59.70
Pihitiwewa Unit 223 - Pahalayakkure	R2 471	5.71	2.15	114.6	9.69	3.19	1.4	38.2	434	33	10.4	412	110	16	14.68	3.04	6.92	2.28	9.20	66.01

Interpretation:	Recommendations:
Low Organic Matter	Apply Nitrogen as required by the crop
Low Potassium in 3 areas	Apply MOP in 3 areas
Low Sulpher, Copper and Zinc	Apply Sulpher
Ca/Mg narrow	Apply Copper in 4 areas
Ca/K also narrow	Apply Zinc in 4 areas

Kg/ Plot/ Application	Initial	Mid	Late
Urea	0.26	0.52	0.78
MOP	0.24	0.48	0.72
MgS_2O_4	0.24	0.48	0.72
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	300	300	300
Foliar Applications of Micronutrients every Week			

Table 11: Fertigation Recommendations per Application per Half Acre Plot

ANNEX 4: TAINUNG PAPAYA CULTIVARS WITH EMPHASIS ON TREE HEIGHT

Tainung papaya is a popular papaya cultivar known for its sweetness, flavor, and disease resistance. The Tainung papaya cultivar comes in several varieties, each with its unique characteristics, including tree height:

1. Tainung No. 1:

Tree Height: Tainung No. 1 is a compact papaya tree that typically grows to a height of around 6 to 10 feet. It is known for its manageable size, making it suitable for home gardens and smaller spaces.

2. Tainung No. 2:

Tree Height: Tainung No. 2 is a larger cultivar compared to Tainung No. 1, with trees reaching heights of 10 to 15 feet. This cultivar is favored for its larger fruit size and vigorous growth.

3. Tainung No. 3:

Tree Height: Tainung No. 3 is a medium-sized papaya tree that can grow to heights of 8 to 12 feet. It strikes a balance between the compact size of Tainung No. 1 and the larger stature of Tainung No. 2.

4. Tainung No. 5:

Tree Height: Tainung No. 5 is another compact cultivar with trees typically growing to heights of 6 to 10 feet. It is valued for its high yield potential and disease resistance.

The choice of cultivar can depend on factors such as available space, desired fruit size, and growth characteristics.

ANNEX 5: MARKET PREFERENCE FOR COMMERCIAL HERMAPHRODITE TAINUNG PAPAYA TREES

The market preference for commercial hermaphrodite Tainung papaya trees has been on the rise due to several factors. This report aims to explore and analyze the reasons behind this growing market preference. The report will examine the advantages of hermaphrodite trees, the desirable qualities of Tainung papaya fruit, disease resistance, and adaptability to diverse climates.

2. Advantages of Hermaphrodite Trees

Hermaphrodite papaya trees possess both male and female flowers on the same plant, allowing for self-pollination. This eliminates the need for additional male trees for pollination, reducing cultivation costs and simplifying farming practices (Aradhya et al., 2009). The self-pollination capability of hermaphrodite trees ensures higher fruit set and increased production, making them more commercially viable.

3. Desirable Qualities of Tainung Papaya Fruit

Tainung papaya cultivars are renowned for their exceptional fruit quality, making them highly sought after in the market. These papayas exhibit a sweet taste, vibrant color, and desirable texture, which are appealing to consumers (Liu et al., 2007). The superior quality of Tainung papaya fruit contributes to its popularity, resulting in increased market demand.

4. Disease Resistance

Tainung papaya trees demonstrate good resistance against various diseases, including papaya ringspot virus (PRSV) and powdery mildew. PRSV is a devastating viral disease that affects papaya crops worldwide. Tainung papaya cultivars have been developed with genetic resistance to PRSV, reducing the risk of crop loss and increasing marketability (Tripathi et al., 2008). This disease resistance attribute contributes to the market preference for Tainung papaya trees.

5. Adaptability to Diverse Climates

Tainung papaya trees are known for their adaptability to different climatic conditions. They can thrive in tropical and subtropical regions, making them suitable for cultivation in various areas around the world (Montero et al., 2010). This adaptability increases the potential market reach for Tainung papaya fruit, leading to a broader consumer base and market preference.

6. Conclusion

The market preference for commercial hermaphrodite Tainung papaya trees can be attributed to their numerous advantages. The self-pollination capability of hermaphrodite trees reduces costs and simplifies cultivation practices. Tainung papaya fruit possesses desirable qualities such as taste, color, and texture, making it highly appealing to consumers. The trees' resistance to diseases, particularly PRSV, ensures crop stability and marketability. Additionally, their adaptability to diverse climates expands the potential market reach. These factors collectively contribute to the growing market preference for commercial hermaphrodite Tainung papaya trees.

References:

- Aradhya, M. K., et al. (2009). Genetic diversity, structure, and differentiation in cultivated papaya (Carica papaya L.) estimated from AFLP markers. Genetic Resources and Crop Evolution, 56(7), 947-962.

1. Liu, Y. C., et al. (2007). Quality characteristics of Tainung No. 2 papaya grown in Taiwan. Food Chemistry, 100(3), 1164-1170.
2. Montero, S. A., et al. (2010). Response of Tainung-1 papaya to salt stress. Journal of Plant Nutrition, 33(9), 1358-1371.
3. Tripathi, L., et al. (2008). Papaya ringspot virus-P: characteristics, pathogenicity, sequence variability and control. Molecular Plant Pathology, 9(3), 269-280.

ANNEX 6: TRANSGENIC PAPAYA VARIETIES DEVELOPED FOR RING SPOT VIRUS RESISTANCE

The Papaya Ring Spot Virus (PRSV) is the most devastating disease of papaya in the whole world. The development of resistant varieties is crucial for sustainable papaya production.

The Tainung papaya hybrid variety, also known as Tainung No. 2 (TN-2), has been widely cultivated and is popular for its sweet and flavorful fruits. However, when it comes to resistance to the PRSV, the situation is interesting.

1. Non-GM Tainung Papaya (TN-2): The non-genetically modified (GM) Tainung-2 (TN-2) papaya variety is commonly grown. Unfortunately, there is no known natural resistance to PRSV in TN-2[1]. In other words, TN-2 is susceptible to PRSV infection.
2. GM Papaya with PRSV Resistance:
    - Researchers successfully generated GM papaya plants resistant to PRSV by cloning the coat protein (CP) gene of PRSV. These GM papayas are specifically designed to combat PRSV infection.
    - Two GM papaya lines, 16-0-1 and 18-2-4, were created. These lines carry the CP gene and exhibit resistance to PRSV.
    - Importantly, a comprehensive food safety evaluation was conducted on these GM papayas. The results showed that they are equivalent in food safety to their non-GM counterpart, TN-2[2].

  - The GM papayas were tested for genotoxicity, acute oral toxicity, and 28-day repeated feeding toxicity. No adverse effects were observed.

3. Hermaphrodite Transgenic Hybrid with Broad-Spectrum Resistance:
    - Researchers have made further progress by developing a hermaphrodite transgenic hybrid with broad-spectrum resistance to PRSV.
    - The CP-transgene insert was identified in a non-coding region of chromosome 3 in the papaya genome.
    - The selected hermaphrodite individual, named TN-2, carries a hemizygotic CP-transgene and exhibits broad-spectrum resistance to different PRSV strains from Taiwan, Hawaii, Thailand, and Mexico[3].

The non-GM Tainung papaya (TN-2) is susceptible to PRSV, but the GM papayas (lines 16-0-1 and 18-2-4) and the hermaphrodite transgenic hybrid (TN-2) offer promising resistance to this destructive virus.

References:

The University of Hawaii has developed transgenic papaya varieties that are resistant to the devastating Papaya Ring Spot Virus (PRSV). These genetically modified papayas have revolutionized the papaya industry in Hawaii by providing an effective solution to the virus that once threatened the livelihood of papaya farmers.

The two commercially successful transgenic papaya varieties developed by the University of Hawaii are known as "Rainbow" and "SunUp." Rainbow papaya is a red-fleshed variety, while SunUp papaya is a yellow-fleshed variety. Both varieties have been genetically engineered to resist PRSV infection through the introduction of the virus coat protein gene.

The commercial success of Rainbow and SunUp papaya varieties underscores the importance of biotechnological advancements in agriculture. These transgenic papayas have not only saved the papaya industry in Hawaii but also serve as a model for combating viral diseases in other crops. The University of Hawaii's pioneering work in developing PRSV-resistant papaya varieties has had a lasting impact on the sustainability and resilience of the papaya industry.

References:

1. Yen, G.-C., Lin, H.-T., Cheng, Y.-H., Lin, Y.-J., Chang, S.-C., Yeh, S.-D., Chan, Y.-C., Chung, Y.-C., & Liao, J.-W. (2011). Food safety evaluation of papaya fruits resistant to papaya ring spot virus. *Journal of Food and Drug Analysis*, 19(3), Article 15.
2. Papaya ring spot disease management: A review
3. Papaya Ringspot Virus in the Garden - Control and Prevention
4. HOW PLANT SCIENCE DEFEATED THE PAPAYA RINGSPOT VIRUS
5. Mapping the CP-Transgene Insert in the Papaya Genome and Developing a Hermaphrodite Transgenic Hybrid with Broad-Spectrum Resistance to Papaya Ringspot Virus
6. Generation of hermaphrodite transgenic papaya lines with virus resistance
7. Screening of papaya common cultivars against papaya ring spot virus (PRSV)
8. Gonsalves, D. (1998). Control of Papaya Ringspot Virus in Papaya: A Case Study. Annual Review of Phytopathology, 36, 415-437.
9. Tripathi, L., & Ntui, V. O. (2013). Biotechnological advances for combating Papaya ringspot virus disease in papaya: RNAi and beyond. Plant Cell Reports, 32(9), 1307-1323.
10. Manshardt, R., & Wenslaff, T. F. (2017). Papaya Biotechnology. In The Papaya: Botany, Production and Uses (pp. 219-250). CABI.

ANNEX 7: IMPORTANCE OF BORON ON PAPAYA CULTIVATION

Boron is an essential micronutrient for papaya plants as it plays a crucial role in various physiological processes such as cell wall formation, sugar transport, flower retention, and hormone development. Boron deficiency in papaya can lead to various issues such as poor fruit set, hollow fruit, distorted growth, and overall reduced yield and quality of the fruit.

The desired levels of boron in the soil for papaya cultivation typically range from 0.5 to 3 ppm (parts per million). It is important to ensure that the soil has an adequate level of boron to support the healthy growth and development of papaya plants.

When a boron deficiency is detected, it is recommended to apply boron to the soil or foliage of the papaya plants. The amount of boron to be applied can vary depending on the severity of the deficiency and the specific recommendations for the particular region or soil type. In general, foliar applications of boron are more effective in correcting deficiencies compared to soil applications.

A common recommendation for boron application in papaya plants is to apply a boron fertilizer containing around 0.3% to 0.5% boron. The application rates can vary, but a general guideline is to apply around 1 to 2 pounds of boron per acre for correcting deficiencies in papaya plants.

It is important to monitor the boron levels in the soil and the plant tissue regularly to ensure that the papaya plants are receiving an adequate amount of this micronutrient.

References:

1. "Boron in Soils and Plants: Reviews" by B. Y. Halpern, M. E. Sumner

2. "Boron Nutrition of Papaya" by C. S. Piper, H. L. Crane