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MINISTRY OF AGRICULTURE, LIVESTOCK, LANDS AND IRRIGATION

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Agriculture Sector Modernization Project

OPERATIONAL MANUAL

APPLE GUAVA

AGRICULTURE SECTOR MODERNIZATION PROJECT

PARK
AGRICULTURE TECHNOLOGY DEMONSTRATION PARK

Prepared by -
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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

Guava (Family Myrtaceae, Genus *Psidium guajava* L.) is a fast-growing evergreen shrub or small tropical tree that can grow to a height of 3-10 m. It has a shallow root system. Guava produces low drooping branches from the base and suckers from the roots. The trunk is slender, 20 cm in diameter, covered with a smooth green to red brown bark that peels off in thin flakes.

Guava cultivated for its edible fruits. Guava trees are native to tropical America and are grown in tropical and subtropical areas worldwide. Guava fruits are processed into jams, jellies, and preserves and are common pastry fillings. Fresh guavas are rich in vitamins A, B, and C; they are commonly eaten raw and may be sliced and served with sugar and cream as a dessert.

1.1 Optimal Ecological Requirements

- Altitude 800 m – 1,000 m above sea level, but it has grown up to 2,000 m.
- Rainfall 1,000 mm – 2,000 mm annually. Rainfall should be evenly distributed over the year for optimal fruit production.
- Growing Temperature 23 ^{0}C – 28 ^{0}C. It can grow at temperatures as low as 15 ^{0}C and as high as 45 ^{0}C.
- pH range 4.5 – 7.0.

Guava is among the most drought resistant tropical fruit crops. It grows on a wide range of soils provided they are relatively well-drained. Guava withstands acidic soils and is tolerant of shade.

Guava trees are well adapted to a wide range of soil types including sands, loams, rock-based soils, and muck. A soil pH of 4.5 to 7 is ideal but plants do well in high pH soils (7.0 - 8.5) if supplied with chelated iron materials and other micronutrients. Guava trees produced by air-layering or cuttings generally have a shallow root system with most roots within 12 to 18 inches (30–45 cm) of the soil surface.

2. LAND PREPARATION

2.1 Primary Land Preparation

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

2.2 Secondary Land Preparation

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

2.3 Tractor

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

2.4 Drainage

1. Light Texture Soils
   a. Sloping handmade ditches to evacuate water from rainfall quickly 30 cm wide x 15 cm deep.
   b. These ditches will discharge into a larger sloping drainage trench 75 cm wide with a depth between 45 cm to 60 cm according to the conditions of the land.
   c. This is a "U" type drainage design for small plots made up of two lateral drainage ditches at the extreme ends of the plot that drain into a primary drainage canal that evacuates the water away from the plot.
   d. Before making the ditches, it is necessary to observe the slope of the plot and the East-West direction of the double row planting. Ideally, the double rows should drain into the lateral ditches without much effort.
2. Heavy Texture Soils
   a. Sloping drainage secondary canals 45 cm wide x 30 cm deep at 20 m intervals.
   b. These canals will discharge into a larger primary type sloping drainage canal 1 m wide with a depth of 60 cm according to the conditions of the land.
3. Waterlogged Soils
   a. Drainage lines 45 cm wide and 45 cm to 60 cm deep at 5 m to 10 m intervals.
   b. These lines will discharge into a larger primary type sloping drainage canal 1 m wide with a depth of 60 cm according to the conditions of the land.
4. Drainage Equipment
   a. Backhoe Excavator or similar with 30cm or 45cm wide bucket.

3. VARIETIES

An article in the Sri Lankan Airlines Magazine[1] in March 2015 described the varieties of guava in Sri Lanka as follows:

Quote *"It's the fruit Mexico gifted to the world. The two- to five-inch-long round or oval bundle of white or red flesh, gift wrapped in a thick hide of green that soon caught the people's imagination and tickled their taste buds when the conquistadors introduced it to the rest of the world. And five hundred years later, Sri Lanka too has started to multiply the guava joy by creating its own varieties to meet the needs of the new millennium.*

When Herman Cortes arrived in 1519 with 500 men and planted his flag and claimed the Aztec Empire in the name of Spain, he came in search of gold. What he also discovered was guava, the tropical fruit of sweet and crisp delight that thrived in the homeland of its birth and would soon command the attention of those far beyond the shores of the then unknown continent.

To the Arabs and the Turks, it was amrood, derived from the Arabic word for pear. To the English, it was guava. To the French it was goyave or goyavier, to the Malaysians it was jambu batu. Each country that welcomed the fruit Psidium guajava, baptized it with its own name. To the Sinhalese it was pera, possibly derived from the Spanish Portuguese name for pear. Its shape resembling the pear may have contributed to its name, but the similarity stops when the first cut or bite is made.

For starters, guava comes in three different tastes. Crispy, crispy, and sweet; or sweet and sour. The fruit, which originated in Mexico and the Central Americas, has today spread to various parts of the world, mainly to the tropics and subtropics. With many countries playing host, the guava comes in many varieties. The most popular kind is called the Apple Guava. Though certain fruits may look like a guava and taste like a guava and even be popularly considered a guava, it may not be one. Take for instance the Strawberry guava which belongs to different genera. The genuine guava is from the Myrtle Family, Myrtaceae.

In Sri Lanka the two kinds of guava commercially cultivated are the Bangkok Giant and a Malaysian variety, which is nameless but is nevertheless loosely referred to in the local market as kilo pera or ata pera. The Bangkok Giant is grown mainly in the Anuradhapura District. It is a round fruit weighing approximately 500 g. The flesh is white, and the taste is crispy and sweet. The skin is dark in its salad days but turns light green in maturity when it is ripe for plucking. The pear shaped Malaysian white variety is oval and bigger and commands the larger share of the market with extensive cultivation done in Kalpitiya, Puttalam, Anuradhapura, Polonnaruwa and Hambantota".

4. PLANTING MATERIAL

Planting material should be seedlings from true seed to improve the genetic material of the guava plot. Main stem height of the seedlings should be 20 cm, with Pencil thick diameter and having at least 3 vigorous shoots with dark green leaves and hard enough for field planting (Annex 1).

The genetic variation in guava seedlings is well known. However, there is a need to improve the guava genetic material due to loss of plantation longevity, the smaller fruit size and the incidence of Guava Fusarium Wilt. This could only be achieved using seedlings from seeds from selected mothers as recommended. Plants that show fruit variation from the Apple guava due to the genetic variation must be replaced.

The use of vegetatively propagated planting material is discouraged. This planting material will not correct the problems discussed above in addition to the risk of spreading the Fusarium Wilt from air layer plantlets produced from Fusarium infected plants. However, it is recommended for the farmers to use selected mother plants, with the new genetic material, from free Fusarium areas to obtain plating material from air layers after the second or third year of production with seedlings, once the desired genetic traits are validated in the field.

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.

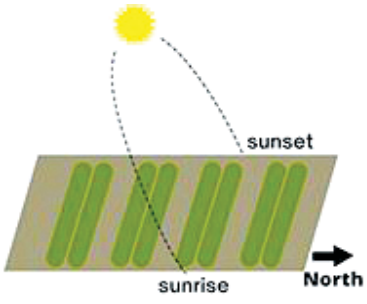


Figure 1: East to West orientation of rows

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 1m 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.

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.

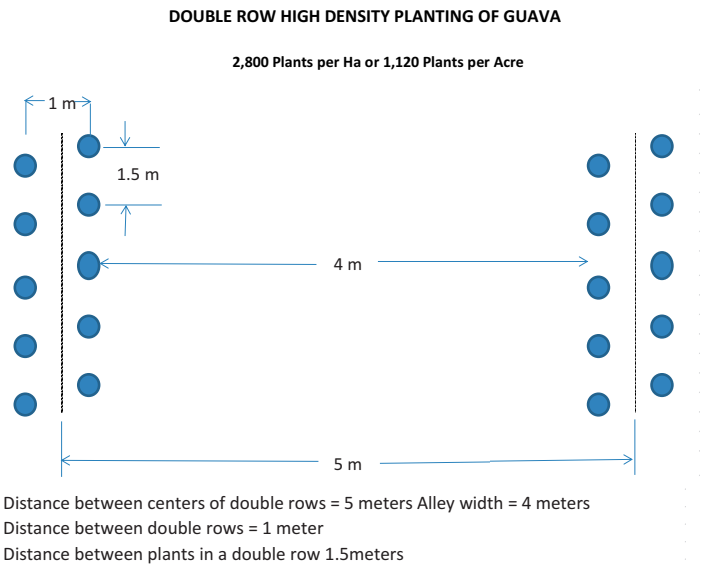


Figure 2: Double row high density planting of Guava

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 Apple Guava plant as required depending on rain fall.

5.2 Plant Spacings Within the Double Rows

Apple Guava	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

Apple Guava 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 3: Micro-Sprinkler System

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

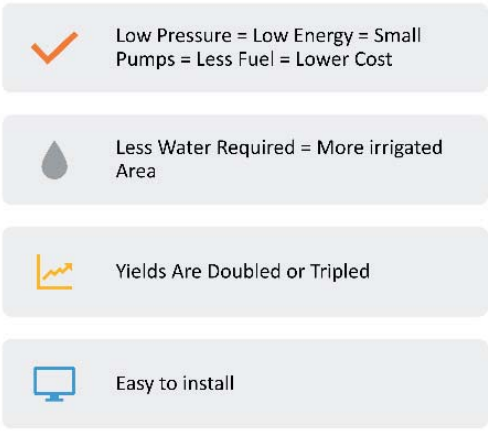


Figure 4: Advantages of low-pressure irrigation

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 Apple Guava 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 apple guava using the micro sprinkler system:

Table 1: Irrigation Schedule

Irrigation Schedule	Year 1		Year 2		Year 3	
Irrigation Time (Hours/ Minutes)	1	22	1	45	1	45

For drip tape, the recommended irrigation time is:

Irrigation Schedule	Year 1		Year 2		Year 3	
Irrigation Time (Hours/ Minutes)	1	10	1	28	1	28

Table 2: Irrigation Schedule (Drip Tape)

6.4 Fertigation

The cultivation of guava with balanced nutrition induces high fruit productivity and quality, with higher post-harvest life and nutritional benefits to human health. Good response of guava to NPK has been widely reported. Additionally, application of Ca, Mg, Zn, Bo has been observed to be essential in given situation.

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 guava Clusters. The results of the Matale, Dambulla tests below will illustrate the process followed to formulate a fertigation program for guava:

The results of the Matale, Guava Cluster area soil tests indicated the following:

Organic matter low except in two locations
Potassium (K) low also the same as Nitrogen (N)
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. Mg dominates. Need for soil amendments with Ca

Therefore, 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
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)
Foliar Micronutrients, especially Cu and Zn, will 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 guava soils in Matale, therefore, lack low amounts of Potassium, about 0.19 meq of Potassium.

This required level of Potassium (0.19 meq) can be converted to an application rate of 150 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 0.19 meq of Potassium are approximately 75 ppm (390*0.19).
- This value of 75 ppm of Potassium is, then, multiplied by 2 to give 150 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 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	150.0	20.0	150.0	50.0
Lb/ acre	150.0	20.0	150.0	50.0
Kg/ acre	68.2	9.1	68.2	22.7

Table 3: Nutrition Quantities

Recommendation	N	P2O5	K2O	CaO
Kg/ Ha	150.0	45.8	180.8	70.0
Lb/ acre	150.0	45.8	180.8	70.0
Kg/ acre	68.2	20.8	82.2	31.8

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

Kg/ Acre	Urea	P Acid	MOP	$CaSO_4$
Fertilizer per year (Season)	148	35	137	103

Table 4: 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	Year 1	Year 2	Year 3+
Urea	119	148	178
P Acid	35	35	35
MOP	137	137	137
CaSO4	103	103	103

Table 5: 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 Apple Guava crop. Therefore, the amounts of fertilizer required per week are:

Kg/Acre	Year 1	Year 2	Year 3+
Urea	4.6	5.7	6.8
P Acid	2.7	2.7	2.7
MOP	5.3	5.3	5.3
$CaSO_4$	4.0	4.0	4.0

Table 6: 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	2.3	2.9	3.4
P Acid	2.7	2.7	2.7
MOP	2.6	2.6	2.6
$CaSO_4$	2.0	2.0	2.0

Table 7: Fertilizer quantities, as per application basis (irrigation cycle)

These amounts are further reduced based on the net area cultivated in Apple Guavas. 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:

Kg/Acre/Application	Year 1	Year 2	Year 3+
Urea	0.25	0.32	0.38
MOP	0.29	0.29	0.29
$CaSO_4$	0.22	0.22	0.22
Applications per week	2		
P Acid Application every two weeks (ml)	175.7	175.7	175.7
Foliar Applications of Micronutrients every two weeks			

Table 8: 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 guava pests and diseases. The Quantity/Intensity factor is a practical and easy to apply IMP concept in deciding whether to apply pesticides:

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

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

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

8.1 Nematodes

Scientific name: *Meloidogyne enterolobii* (Guava root-knot nematode)

This nematode is a highly pathogenic and invasive nematode species. It is an aggressive, microscopic parasitic worm. Despite its common name, it has a broad host range including many vegetable crops, ornamental plants, and weeds. It has been identified as a high priority pest for ginger, papaya, potato, sweet potato, and vegetable industries.

The guava root-knot nematode poses risk due to its widespread distribution and extensive host range. This species is recognized as the most virulent root-knot nematode (RKN) species because it can emerge and breed in plants that have resistance to other tropical RKNs.

Cause

Like other root-knot nematode species, guava root-knot nematode induces galls on the roots of infected plants. In severe cases, extremely large and numerous galls can be found. Above-ground symptoms include stunted growth, wilting and leaf yellowing. Crop yield can be greatly reduced, and the quality of root and tuber commodities severely affected. In addition, guava root-knot nematode infection may favour further attacks on roots by secondary plant pathogens, such as root-rotting fungi.

Guava root-knot nematode is very damaging due to its ability to develop and reproduce on crops that are resistant to other species of *Meloidogyne*. It also has a higher infection rate and induces more severe root galling than other species of root-knot nematode.

GRKN affects the following:

- horticultural and agricultural crops
- ornamental plants
- some weed species.

The pest is considered significant because of its:

- wide host range
- high reproduction rate
- severity of induced abnormal growths
- impact on yields in preferred hosts.

Description

The appearance of guava root-knot nematode is very similar to other species of root-knot nematode. All life stages of *M. enterolobii* are microscopic and require magnification to be seen.

At most life stages the GRKN is microscopic. This makes it extremely difficult to detect, especially:

- in soil or
- prior to symptom development in infected hosts plants.

Second stage juveniles are translucent and vermiform (worm-shaped), with a tapered tail and rounded head with a delicate stylet.

Females are white, pear-shaped with projecting necks tapering to the head, and can be variable in size.

Males are translucent, vermiform (worm-shaped), with a rounded head and blunt, rounded tail. They are much larger than juveniles with a more robust stylet and head framework.

Symptoms

Symptoms caused by guava root-knot nematode are similar to those caused by other species of root-knot nematode, although on certain crops, symptoms of guava root-knot nematode infection are more severe than other species of root-knot nematode.

Typical symptoms include severe galling (knotty root growths stimulated by nematode infection) of the root system, and above ground symptoms such as stunted growth, wilting, and leaf yellowing, which may resemble water and nutrient stress.

Guava root-knot nematode also directly infects edible below ground parts of the plant, like bulbs (e.g., nutgrass), rhizomes (e.g. ginger), swollen roots (e.g. sweet potatoes), and tubers (e.g. potatoes). These can be severely deformed with large galls, a dark and cracked surface, and white round females can be found under the surface when cut open and examined with a microscope or hand lens.

GRKN is reliant on live roots to feed and reproduce. Typical symptoms of GRKN infection includes abnormal growths or knotting on roots caused by the pest feeding. This affects the plant's ability to uptake nutrients and leaves it susceptible to secondary pathogens.

Above ground your plant may display:

- stunted growth
- wilting
- yellowing of leaves.

This can often be mistaken for water or nutrient deficiency. It's important to check your roots for signs of the pest.

Distribution

Internationally, guava root-knot nematode is found in tropical to subtropical areas of the world, including Central and South America, Africa, and Asia. More recently, it has been identified in several countries in Europe and the Mediterranean. It has been detected in Australia – in Queensland and the Northern Territory.

Guava root-knot nematode is found in tropical to subtropical areas of the world including:

- Central and South America
- Africa
- Asia
- several US states
- some European countries (in greenhouse settings).

Hosts

Guava root-knot nematode is highly polyphagous with a broad host range including but not limited to:

• coffee • cotton • ginger • guava • ornamental plants • papaya • soybean and common bean • sweet potato	• vegetables • watermelon • tobacco • weeds. • cucumber • capsicum • eggplant • butternut pumpkin • snake bean	• zucchini • chilli plants. • melon • tomato • ginger

Life cycle

The life cycle of guava root-knot nematodes is very similar to other root-knot nematodes.

The eggs hatch as second-stage juveniles into soil. These juveniles then migrate in water films through the soil searching for susceptible host roots. Juveniles are the only infectious life stage. Once a suitable root is found they invade the root tip and establish a permanent feeding site, where the third and fourth stage juveniles and developing adults feed.

The plant responds to the nematode invasion with root cells surrounding the feeding site enlarging and multiplying, to form a gall in which the juveniles and developing adults are embedded.

The juveniles eventually develop into globose females or vermiform (worm-shaped) males.

Females produce eggs which are deposited into a gelatinous matrix known as an egg mass outside the gall. A single female can produce 500–1000 eggs. Mature males cease feeding and exit the roots. Males are not required for reproduction (mitotic reproduction). Juveniles hatch from eggs in the soil or root debris, and travel through soil to invade new roots. They feed on roots, and this stimulates cells causing root tissue to enlarge and form an abnormal growth.

Mature females lose their mobility and become sedentary. They can:

- produce eggs without males
- lay eggs either inside or on the root surface.

The eggs hatch immediately or can become dormant. Eggs can survive in the soil (without a host) for up to 12 months. The pest takes about 4 - 5 weeks to complete its life cycle. Females can produce 400 - 600 eggs in this time.

Spread

As with all root-knot nematode species, guava root-knot nematode can be easily transmitted with soil and plant material. Infested soil and growing media, plants for transplanting, bulbs, and edible tubers from sites where guava root-knot nematode occurs are the most probable pathways of introduction into new areas. Soil attached to machinery, tools, footwear or plant products are other possible pathways.

GRKN, like most root-knot nematodes, can't move far on its own. In the soil, their movement is limited to a few centimeters. Annually they may move a few meters.

The pest can be spread or introduced to new areas by:

- movement of infested plant material - host plants with roots
- soil - as is
- soil attached to equipment, machinery or plant parts
    - e.g corms, rhizomes, bulbs, or hosts and non-host plants with soil attached.

It can also be spread from property to property and on property through infested soil attached to footwear and tools. It's important to maintain good biosecurity hygiene practices. Irrigation water can also provide another dispersal mode on an infected property.

Monitoring and Action

Inspect crops regularly for plants with poor vigor, stunting or reduced yield and if detected, inspect underground plant parts for the presence of galls.

Prevention

There are simple steps you can take to protect your farm or property:

- Source planting material from reputable certified suppliers and request a written statement indicating the absence of plant-parasitic nematodes.
- Ensure planting material is free from soil and plant residues.
- Keep records of where plants/planting material/tubers are sourced from, and where and when they are planted on your property.
- Check planting material on arrival to make sure they look healthy and visibly free of all pest and disease symptoms.
- Regularly check your farm and report any unusual or unfamiliar symptoms or damage to plants.
- Limit movements of soil
- Follow good hygiene practices
    - e.g. washing soil from machinery and equipment prior to being brought onto the property, chemical footbaths etc.

Commercial growers should have an on-farm biosecurity plan to reduce the risk of introduction of plant pests and disease onto their property.

The ISP strategy for the prevention of nematode damage to guava is to always maintain the guava plants vigorous and healthy by following all recommended cultural practices in the ISP technology package properly.

Chemical Treatment

Velum Prime nematicide is recommended as a chemical treatment. There are several ways to use this product:

1. At the nursery when preparing seedlings for planting material by drenching the growth medium with Velum Prime when the seedlings are about 5 cm to 10 cm tall. Use a dilution factor of 1.6 ml of Velum Prime per 4 liters of water.
2. In the planting hole before planting also by drenching using the same dilution factor of 1.6 ml of Velum Prime to 4 liters of water.
3. In the field to prevent damage:
    a. Through the low-pressure irrigation system at a rate of 250 ml of Velum Prime per Acre.
    b. As a drench around the tree every 3 months using a dilution factor of 1.6 ml of Velum Prime to 4 liters of water.
    c. As a drench around the tree every 6 months using a dilution factor of 3.2 ml of Velum Prime to 4 liters of water.

The user must follow the product label for Velum Prime, including all recommended safety precautions.

8.2 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 5: 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.

8.3 MEALY BUGS

Scientific name: *Rastrococcus spp.*

Figure 6: Mealy Bugs

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.

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.

8.4 FUSARIUM WILT OF GUAVA

***Fusarium* Sp**

Fusarium Wilt is the most destructive disease for the guava tree in Sri Lanka and losses due to this disease are substantial. It occurs from Sri Lanka to Latin America, Malaysia, Pakistan, South Africa, South Asia, and Taiwan.

Description

The guava wilt is encountered especially in alkaline soils and the symptoms are browning and wilting of the leaves, discoloration of the stem and death of the branches along one side. Sometimes the infection girdles the entire stem and the whole plant may wilt. In severe cases the entire tree may die.

The disease is soil-borne and is predominantly caused by the species of *Fusarium*, of which *F. oxysporum* is generally the main cause. The other species of *Fusarium* i.e., *Fusarium solani* also dominates in isolation. Since the disease results in the complete mortality of the affected plants, the loss is total and severe also in monetary terms due to the loss of labor and inputs during several years of cultivation.

Fusarium Wilt is the only disease of guava which is threatening guava cultivation in Sri Lanka.

Favorable Conditions for the Development of the Disease

Though *Fusarium oxysporum* may be found in many places and environments, development of the disease is favored by high temperatures and warm, poorly drained soils.

The optimum temperature for growth on artificial media is between 25-30 °C, and the optimum soil temperature for root infection is 30 °C or above.

Spread

Fusarium is spread in contaminated soil and infected cuttings and is favored by warm temperatures, high relative humidity, overwatering, and poor drainage. Fusarium disease on guava trees is difficult to control. Prevention is the best approach to managing disease.

Prevention

- Avoid planting in poorly drained soils. In high rainfall areas, macro level drainage works as well as farm level drainage practices must be implemented.
- 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 guava tree.
- Fertilize and irrigate trees properly to improve tree vigor.
- Pruning of crowded branches (after harvest) allows light penetration and improves air circulation, creating an environment unfavorable for pest development.
- Field Sanitation: Under brushing and clearing of surroundings.

8.5 LEAF CHEWING CATERPILLAR

Description

Caterpillars, the larvae of butterflies and moths, damage plants by chewing on leaves, flowers, shoots, and fruit and sometimes other parts of the plant. Caterpillars hidden in rolled leaves or among foliage can be difficult to see or manage. However, many plants, especially perennials, can tolerate substantial leaf damage, so a few leaf-feeding caterpillars often aren't a concern. Handpicking and natural enemies often provide sufficient control.

Prevention

- Early detection and removal prevent excessive damage.
- Look for feeding holes, excrement, webbed or rolled leaves, caterpillars, and eggs.
- Prune off rolled or webbed leaves and handpick caterpillars from plants. Destroy the insects by crushing them or by dropping them into soapy water.

Control by Natural Enemies

- Beneficial insects and other organisms often prevent caterpillar numbers from rising to damaging levels.
- Most caterpillar species have several species of parasitic wasps or flies that attack them. Look for parasite cocoons next to caterpillars, darkened caterpillar eggs, or exit holes in dead caterpillars.
- General predators include birds, assassin bugs, lacewings, predaceous ground beetles, and spiders.
- Naturally occurring diseases caused by viruses, bacteria, or fungi often kill caterpillars.

Pesticide Use

- Use insecticides only when damage is intolerable, nonchemical methods haven't worked, and smaller caterpillars are present. Avoid insecticides that can kill beneficial insects. Don't treat butterfly garden plants, otherwise you'll kill the caterpillars that will become butterflies.
- *Bacillus thuringiensis,* subspecies *kurstaki* (Btk), is a microbial insecticide that kills only caterpillars. It's safe to use near bees, beneficial insects, and wildlife. Caterpillars must feed on treated leaves to be affected. Because Btk is most effective on small, newly hatched caterpillars and breaks down rapidly, treatment timing is critical.
- Spinosad is a safe microbial-based insecticide but can have negative impacts on some beneficial insects.
- Caterpillar attacks have been controlled in the Guava Cluster in Matale by spraying with Chlorantanipol (Coragen) at a rate of 4 ml of product to 16 liters of water (1 knapsack tank). Approximately, 10 full tanks will be required per acre (40 ml of Coragen per Acre).

9. PRUNING

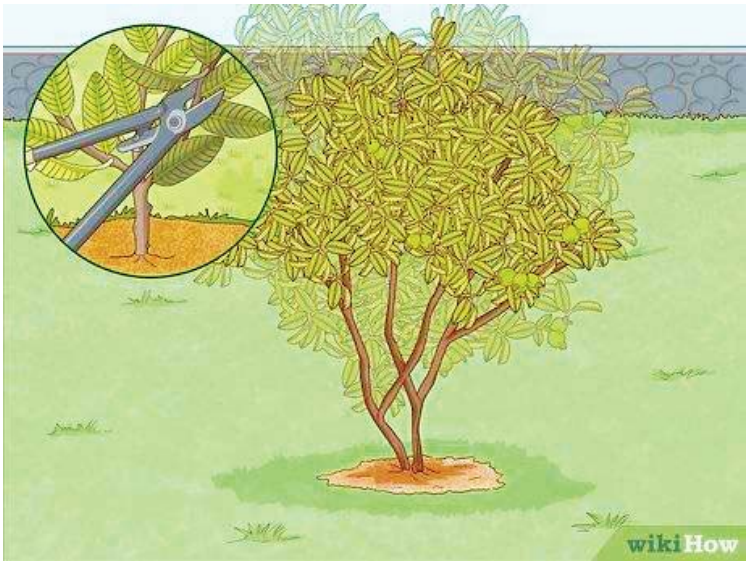
9.1 Tree Architecture

- Tree architecture or formative training begins when the seedlings are about 0.7 m 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 creation of several tiers of lateral branches must continue to generate the preferred shrub type tree architecture for guava.
- Guava plants should develop into strong and well-shaped shrubs within the first 2 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 narrow shrub architecture of the tree.

9.2 Pruning Mature Trees Bearing Fruits

Three types of cuts are used on guava trees, thinning cuts, heading back, and pinching:

1. Thinning helps counteract the tree's dense growth by letting light and air into the inner branches, which helps them stay healthy and productive. It also makes the fruit easier to reach. To thin, simply remove some of the branches by cutting them at their base.
2. Heading back means pruning individual branches to reduce their length. These techniques allow you to control the horizontal spread of the tree.
3. Pinching means removing the growing tip of shoots. Farmers use pinching to stimulate quick fruiting.



Guava flowers on new growth, so these cuts also induce the tree to produce more flowers and fruit.

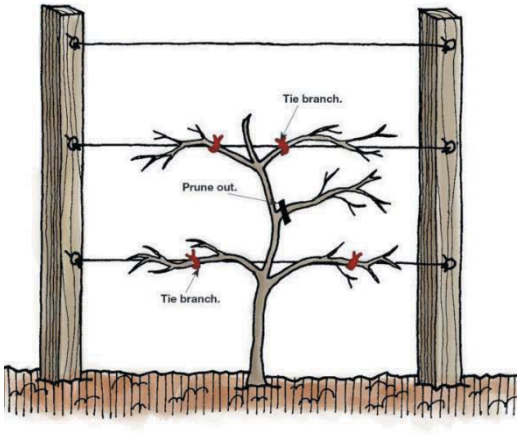
Guavas should be pruned annually once fruiting has finished. Pruning ensures the shrub does not grow into a large tree which makes it difficult to collect the fruit. Aim to keep the tree around 2-2.5 meters high and about 1.5 across. Annual pruning also helps to open the tree to improve light penetration, which helps the color of the fruit. In addition:

Some additional pruning tips are:

- remove crowded branches or those that are already dried up; affected by insect pests and diseases.
- it should be done, preferably, after harvest.
- it should be done only within the canopy.
- avoid excessive pruning on fruit-bearing trees, Minimal pruning for small trees and open center for big trees.
- to change the variety or to rejuvenate old trees, drastic pruning is recommended.

9.3 Espalier Trellis System

- The espalier trellis allows for the total control of the architecture and growth of the guava tree to make it easier to manage i.e., spraying, pruning, harvesting, and other practices are made much easier to manage.
- The espalier trellis production system for guava 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 fourth 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.
- The Espalier Trellis applies the new biological concept of "less biomass more flowers and more fruit".
- First, 4"- 5" diameter wooden posts are placed 6 meters apart inside guava tree rows (middle of double row).
- 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 guava branches to trellis.
- Water suckers and very low branches are removed before trellising the tree.
- Small trees must be taller than the first wire on the trellis which is 0.5 m high from the ground level.
- When the tree height is at least 10 cm above the 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.
- Avoid pruning immediately above a whorl of leaves. This weakens the tree.
- Avoid working with very new and young branches (flush) developed after clipping the tree off.
- Once the new lateral secondary branches are matured, they can be bent and tied along the wire.
- Do not tie too tightly to allow the lateral branches to grow in diameter.
- These secondary branches are trained along the wire to increase the width of the guava tree on the trellis.
- 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 treetop must be secured to the wire after it grows past the wire.
- One of the tertiary branches developed from pruning 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 fourth tier branches can be allowed to flower if they are well positioned.
- Do not over-prune the tertiary or fourth tier branches. This will delay flowering.
- A ladder is used to work on high trees.
- After harvesting the trellised guavas, manual pruning of tertiary and fourth tier branches completes the preparation for the next harvest.

9.4 De-Blossoming

The process of removing flowers in guava trees makes possible the shifting of production from one period to another perhaps more favorable marketing period. It can also delay production by 6 to 8 weeks.

10. INTERCROPPING

- The double row and high-density planting system is very well suited for intercrops with the guava 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 guava 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 guava tree and the fruit must be avoided as well in intercropping.

11. FLOWER INDUCTION

Fruit	Growth Regulators	Chemicals	Pruning	Other
Guava	Ethrel (Ethephon)	Urea	Pinching of Matured Terminal Branches	Irrigation Stress

Table 9: Flower Induction

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

- Applying an Ethrel-Urea 1:1 mix on the foliage of the tree.
- Pinching the terminal buds or branches of matured guava trees. This method produces a quick flowering response and is used as a regular practice by farmers.
- Induced physiological stress: ✓ Deprive the trees of nutrients and/or water.

12. BAGGING

Bagging guava fruit is now a common practice to prevent damage from fruit flies 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 guava on the tree. This inventory is determined 6 to 8 weeks before harvest. In other words, the farmer will know 1 to two months in advance how much guava 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 guava based on the inventory.

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

43	22-Oct	28-Oct	White and Blue	W/B	
44	29-Oct	4-Nov	White and Red	W/R	
45	5-Nov	11-Nov	White and Purple	W/P	
46	12-Nov	18-Nov	White and Green	W/G	
47	19-Nov	25-Nov	White and Yellow	W/Y	
48	26-Nov	2-Dec	White and Blue	W/B	
49	3-Dec	9-Dec	White and Red	W/R	
50	10-Dec	16-Dec	White and Purple	W/P	
51	17-Dec	23-Dec	White and Green	W/G	
52	24-Dec	30-Dec	White and Yellow	W/Y	

Calendar from late October to December 2023:

Fruits should be bagged after flowering at the ‘ping pong” size stage.

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 Guava 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 6 to 8 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 6- and 7-week-old fruit and harvest those that are ready according to the buyer's specifications for maturity index and appearance. All the 8-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 5, 6 and 7. If the fruit is growing slowly, we can increase the age by one week i.e., 7, 8 and 9.

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.

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

Guavas are picked by hand, and in general, guava fruits are usually picked before they are fully ripe and after they develop a yellow blush colour on 1/3 to ½ of surface of the fruit. The fruit bruises easily and must be handled carefully to avoid damage.

13.1 Harvesting Indexes

- Maturity Period: 6 – 8 weeks after bagging.
- Some indicators of maturity include:
    - Skin changes from green to yellow blush on 1/3 to ½ of the skiing surface.
    - Skin becomes shiny or glossy.
    - Sugar content increases but the fruit remains crunchy to taste.

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 without pedicels or fruit stems.

14. POST-HARVEST HANDLING

14.1 Guava Postharvest Facts

- Guava is a climacteric fruit, meaning they continue to ripen after harvest.
- The optimal temperature for storing Guava is between 8°C and 10°C (46°F and 50°F). More mature or ready to eat Guava can be stored at 8°C (46°F).
- Guava 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 Guava is between 85% and 95%.
- Guava produces ethylene gas, which can cause them to ripen more quickly. However, the rate of ethylene production by guava is less than other climacteric fruits. Nevertheless, it's best to store Guava separately from other fruits and vegetables sensitive to ethylene.

14.2 Guava Product Specifications

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

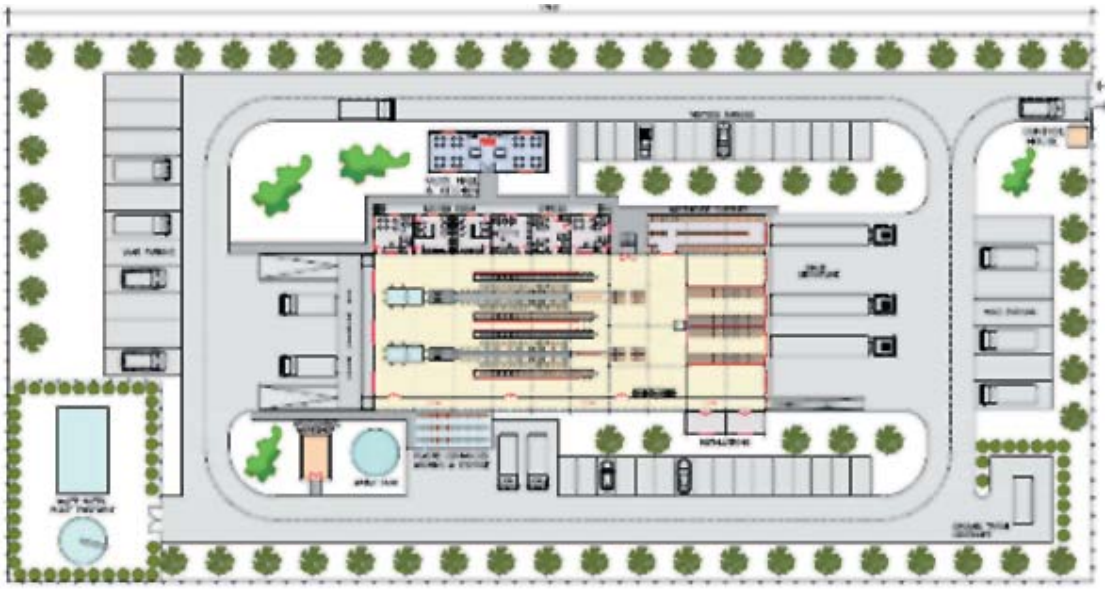
- Export Containers - Corrugated cardboard boxes containing 5 Kg net of fruit on arrival.
- Shipping fruit weight – 5.3 Kg to 5.5 Kg.
- Maturity Stage – Mature green to mature depending on voyage time to market.
- Maturity Tolerance – 5% to 10% by weight (2 to 3 guava fruits per box).
- Sanitary and Phytosanitary Condition – Fresh and free from blemishes, diseases, and pests.

Count per Box: The Guava market uses the count of fruits per box (count) to differentiate guava 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	Guava Weight (gm)	Count per Box
Large	250 – 350	14 – 20
Medium	150 -249	19 - 33
Small	75 – 149	32 - 67

Based on Shipping Weight of 5.3 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

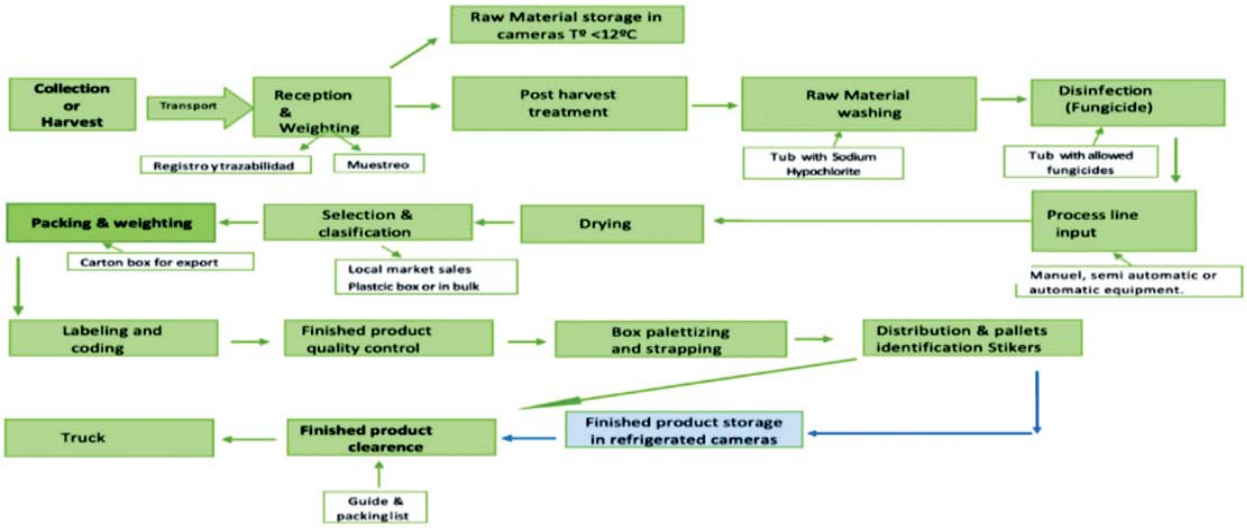


Table 10: Post Harvest Fruit Treatment Flow Diagram

Guavas 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.

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

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.

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 guavas 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 Guava 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 7: Packaging House Sanitation

14.9 Storage Tips

- Mature guavas 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 %).
- Guavas 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 guavas that consumers prefer.

15. EXPORT PROTOCOL

15.1 Guava Shipping Reefer Containers

Guavas 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 guava 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 for a normal reefer and 12 x 16 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 Guava. There is usually an upfront charge for palletized fruit to offset the cost.

The temperature for holding and shipping guava 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. Guava 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 8: Reefer Container

Figure 9: Reefer Container Settings Panel

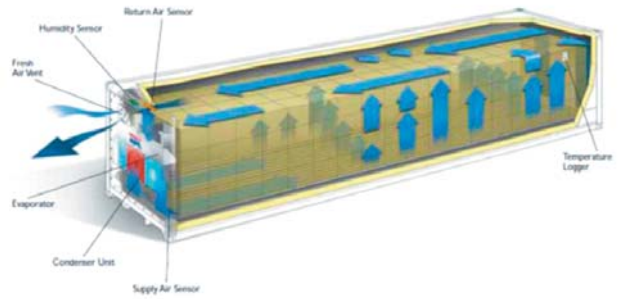


Figure 10: Reefer Container Cool Air Flow

Figure 11: Temperature Monitoring Device

Figure 12: Loading Guava in Reefer Container

15.2 Mixed Guava Containers

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

Fortunately, Guava can be shipped in small volumes together with other compatible products such as King Coconut. This alternative will benefit the Guava export industry because it will assure weekly deliveries of Guava 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

Item	Unit	Without project	With Project
Fresh Production /ha	mt	30	67
Production Waste	%	20%	20%
Sales Volume/ha	MT	24	54
Cost of Production/ ha	LKR	659,525	2,688,533
Cost/Kg	LKR	28	50
Selling Price/Kg	LKR	80	180
Gross Income/ ha	LKR	1,896,000	9,684,000
Gross Margin/ ha	LKR	1,236,475	6,995,467
Benefit/Cost Ratio		**2.9**	**3.6**

ANNEX 1: SPECIFICATION FOR GUAVA PLANTING MATERIAL

Supplier

1. Suppliers 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 not infected with Nematode by testing random samples (the PPMU's must support this task. Supplier has to bear the cost of testing).
4. Preference should be given to suppliers within the district to minimize physical damage in transportation as well as to minimize transportation cost.

Seedlings

1. Seedlings from true seeds will be used for planting material to improve the genetic material of the plot.
2. Seedlings must be grown in black color Polyethylene bags. The s size of bags should measure as diameter 12.5 cm and height 20 cm.
3. Bags must be filled with compost mixture as the potting media.
4. Plants should be placed in the center of the bag to allow for a well-developed root system.
5. Seed should be obtained from healthy plants identified by the Range Agriculture Instructor
6. Main stem height of the plant should be 20 cm, with Pencil thick diameter and having at least 3 vigorous shoots with dark green leaves and hard enough for field planting.
7. The plant must reflect the characters of the variety.
8. Seedlings 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 GUAVA

	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
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

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	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	Initial	Mid	Late
Urea	0.25	0.31	0.38
MOP	0.29	0.29	0.29
$CaSO_4$	0.22	0.22	0.22
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	174.3	174.3	174.3
Foliar application of micro-nutrients every two weeks, especially Cu and Zn			

Table 12: Fertigation Recommendations per Application per Half Acre Plot

SOIL TESTS RESULTS IPOLOGAMA GUAVA

Sample Code	Lab No.	pH	OM	EC	Ca	Mg	K	NH_4-N	P	S	Cu	Fe	Mn	Zn	CEC	Cation Ratios				
		1:2.5, H_2O	%	µS/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/kg	Ca/Mg	Ca/K	Mg/K	Ca+Mg/K	Ca Sat.
B. A. S Jayathissa	R4 459	7.42	1.34	150.8	5.81	2.47	1.09	30.0	21.0	20.0	5.1	178.9	54.1	1.1	9.37	2.4	5.3	2.3	7.596	62.0
U. R. M. U Silva	R5 459	7.36	1.48	60.9	3.41	1.98	0.32	53.6	17.0	23.0	12.3	281.5	129.4	3.8	5.71	1.7	10.7	6.2	16.844	59.7
K. M Hemasiri	R6 459	6.25	1.75	80.2	2.62	1.50	0.31	59.5	41.0	30.0	5.4	658.0	88.0	1.5	4.63	1.7	8.5	4.8	13.290	56.6
E. M Premawathi	R7 459	6.78	0.81	88.7	3.16	2.14	0.25	48.2	22.0	14.0	3.2	508.0	116.0	1.1	5.53	1.5	12.6	8.6	21.200	57.1
Jayathilake Yapa	R8 459	6.64	0.67	57.7	1.12	0.87	0.18	70.3	18.0	29.0	1.7	178.0	11.1	0.7	2.17	1.3	6.2	4.8	11.056	51.6
H. M. S. L Herath	R9 459	6.42	1.21	105.9	1.74	1.27	0.94	60.1	41.0	18.0	3.1	610.0	140.0	1.8	4.15	1.4	1.9	1.4	3.202	41.9
M. M. Chandralatha	R10 459	6.68	0.81	117.2	2.91	1.53	0.21	72.1	23.0	19.0	4.5	204.6	18.6	1.2	4.65	1.9	13.9	7.3	21.143	62.6

Interpretation:

Low Organic Matter
Low Potassium
Low Sulphur, Copper and Zinc
Low Cation Ratios
Low Calcium Saturation

Recommendations:

Nitrogen as required by the Crop
Dolomite at land preparation
MgS2O4
MOP
Foliar micronutrients mix

Kg/ Plot/ Application	Initial	Mid	Late
Urea	0.13	1.03	0.58
MOP	0.25	0.18	0.24
$CaSO_4$	0.55	0.40	0.53
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	281.7	207.3	273.8
Foliar application micro-nutrients, recommended biweekly, especially Cu and Zn			

Table 13: Fertigation Recommendations per Application per Half Acre Plot