MANAGING BIOTIC STRESSES, REJUVENATING AND INCREASING PRODUCTIVITY AND REVITALIZING COCONUT INDUSTRY IN MALDIVES

Final Report

By

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EXECUTIVE SUMMARY

On the request of the Government of Maldives the Food and Agriculture Organization deployed three consultants; Dr. L. C. P. Fernando, Biotic Stress Management Specialist, Mr. P. A. Henry Nimal Appuhamy, Crop Production and Technology Dissemination Expert and Dr. S. M. M. Samarakoon, Industry and Value Chain Expert to assist the Government in managing biotic stresses, particularly identifying and managing the fast-spreading pest, rejuvenating and increasing productivity, and improving supply and value chain to revitalize the coconut sector in the country. The consultants visited several Atolls of Maldives during 16 August – 06 September 2023 and assessed the status of pest infestations, coconut cultivation and supply and value chain activities and identified the gaps to be addressed in revitalizing the coconut sector. Specimens of insects were collected for identification. The Biotic Stress Management Specialist made a second visit on 31 October – 06 November to train the staff on monitoring and mass culturing of parasitoids.

The observations revealed that the fast-spreading pest outbreak in Maldives is due to a whitefly insect species and the black sooty mould found on infested leaves is a secondary attack of a fungus growing on honey dew secreted by the whitefly. As a result of adult and immature whiteflies feeding on the sap of lower surface of leaves, the damage initially appears as yellow spots and with progress of infestation the patches coalesce, leaves turn yellow and dry off. According to the morphological analysis of the pest puparia at the laboratory of the Coconut Research Institute of Sri Lanka, it was confirmed that the predominant whitefly species infesting coconut as *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), commonly known as Rugose Spiralling Whitefly. Another whitefly species co-existing with *A. rugioperculatus* was confirmed as *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae), the Bondars' nesting whitefly. This is the first record of their occurrence in the Maldives. At the time of the visit whitefly outbreak was largely subsided. The pest damage was absent in some localities while it was found in varying degrees in others. However, reinfestation has started on the damaged palms. The samples collected from many localities showed presence of parasitism on *A. rugioperculatus* puparia. Taxonomic identification confirmed the parasitoid as *Encarsia guadeloupe* (Hymenoptera: Aphelinidae). The parasitism levels were increasing and was high as over 50%.

Hispid beetle, *Oryctes* beetle and rat damages were prevalent in many islands. Hispid beetle damage ranges from mild to moderate level. In many areas *Oryctes* beetle damage is not at an economically damaging level. No coconut diseases were observed. Deficiencies in present Plant Quarantine System, lack of continuity of pest monitoring and management programmes, inadequate training of staff and pest management facilities and poor interest and awareness among public are the main factors contributing to new pest introductions and pest damages.

It was noted that the coconut cultivation in the Maldives is in a crisis. Although the country has fertile soil, favourable climate, and high ground water table, which are ideal factors for profitable cultivation of coconut, this existing natural potential has not been exploited adequately due to various administrative, social, economic, and poor attitudes of farmers and officers. The sector development and productivity enhancement activities at the council level has not given adequate recognition, priority, and assistance. It was identified that insufficient availability of technology, poor technology dissemination strategies, lack of farmer education, poor advisory and training and farmer support services are the major contributary factors for the prevailing situation. Negative attitudes and insufficient technical knowledge of people and officers on coconut production has caused adverse effect on the sector development activities. Close planting and leaving fallen nuts to germinate *in situ* leading to high density coconut holdings and neglected of coconut cultivation are the major factors contributing to the decline of the sector. The declining production and profitability have pressurized people to further neglect their plantations.

There are extremely limited coconut industries currently operating in the Maldives and they too are carried out in a small scale. In general, Maldivian coconut sector has no organized supply and value chains. Value addition of coconut is barely done and there are no large-scale industries for processing of coconut. The gaps in value chain were identified as poor nut delivery to the industry, high transportation cost for marketing, lack of interest given by the government, shortage of labor, inadequate warehouse facilities, poor infrastructure, and frequent price fluctuations of coconut in the islands and the Male markets.

To mitigate possible future pest invasions, the Biotic Stress management recommends strengthening of the Plant Quarantine system by conducting Pest Risk Analysis for each species of palms imported from each country, imposing adequate phytosanitary conditions for each consignment of importation and develop post entry quarantine facilities. It is also important to implement surveillance and pest monitoring mechanism by a team of officers dedicated for this purpose. The team may also implement the pest management strategies for each pest continuously. The capacity of the team must be developed by providing adequate training and laboratory facilities. Regular awareness programmes to farmers and public are essential to receive their support in the activities.

As immediate action for the management of whitefly it was recommended to spray young palms in localities where pest is in very low numbers with 1% neem oil and soap mixture and prohibit/ avoid transportation of infested material from infested islands to other with no infestation reported. As a sustainable method of management, biological control using parasitoids is highly recommended. Since whitefly parasitoids are not commercially produced elsewhere, initiating of a mass production programme of parasitoids in Maldives is recommended for augmentative releases, whenever necessary.

Training was given to the officers in mass production of parasitoids and monitoring pest populations in the field. It is proposed to re-establish the mass production facility for Hispid beetle parasitoids and commence releasing them in the field.

Considering the limited land availability for coconut and competition from other land users the most suitable approach to revitalize the coconut sector in the Maldives would be to effectively manage existing coconut cultivation to increase yield and land productivity, harvest coconut to increase the nut supply, reduce crop losses due to pests and introduce technology to add value to stimulate the development of the coconut industry and improve profitability.

Technology is the key requirement for ensuring high land production and profitability of the coconut sector. Firstly, the highest priority should be given in preparing a comprehensive "Coconut Technology Guide" for the use of officers and farmers to follow in rehabilitating the coconut holdings. Selection of mother palms with desirable characters to collect seed nuts, establishment of coconut nurseries to supply high quality planting material for planting programs, adoption of measures to enrich the soil fertility levels and to reduce the effect of nutrient deficiencies, application of fertilizer to enhance nut production are the major needs of the sector. Immediate strategies and agronomic interventions required to rehabilitate the coconut farming sector are reported. It is proposed to establish a "Coconut Development Unit" under the Ministry to take care of all activities in relation to coconut development. The capacity of the officers of this Unit may be developed by providing intensive training on coconut cultivation, pest management, value chain development and innovative methodologies for farmer training. Policy changes required in land use to encourage offices and farmers for cultivation of coconut is discussed.

Industry and value chain specialist identified strategies and activities for the development of the Maldives coconut industry. It is proposed to collect a complete census of the number of coconut trees, the extent under coconut, and the total coconut production in the Maldives, initially. Harvesting mature coconut monthly or bi-monthly to reduce crop loss, developing an effective value chain network to connect farmers to markets and boost value-adding activities through improved technology and continuous inputs supply, processing, and exporting finished products from the coconut growing Islands to Male, resorts, and niche markets are recommended. The proposed potential value-added products are coconut oil, virgin coconut oil, coconut ice cream, bottle coconut water, coconut timber, and the processing of shell and coir products, among others. Virgin coconut oil and it related products, coconut ice cream, coir products could be developed immediately with geographical indicators (GI) to cater resorts and niche markets with exceptional value.

The strategies to address the existing gaps of the coconut sector are discussed in detail with relevant information/ literature and a strategic plan with short-, medium and long-term measures are outlined.

INTRODUCTION

The Maldives, situated in the Indian Ocean is comprising of a territory spanning roughly 90,000 sq. km. including the sea and a land area of 298 sq. km. comprising of all the islands. The Maldives' chain of 26 atolls stretches across the equator lying between latitudes 1°S and 8°N, and longitudes 72° and 74°E. It is the lowest country in the world, with maximum and average natural ground levels of only 2.4 m. and 1.5 m. above sea level, respectively. The average high temperature is 31.5^0C and the average low temperature is 26.45^0C. It has a tropical monsoon climate; the dry season associated with the winter northeastern monsoon and the rainy season associated with the southwest monsoon which brings strong winds and storms. The annual rainfall averages 254 cm. in the north and 381 cm. in the south. The shift from the dry northeast monsoon to the moist southwest monsoon occurs during April and May. During this period, the southwest winds contribute to the formation of the southwest monsoon, which reaches the Maldives at the beginning of June and lasts until the end of November.

Agricultural land in Maldives is 23.3% of the land mass consisting of 10% arable crops, 10% permanent crops and 3.3% permanent pasture. Forest land is 3%. Other areas are made of sand, mangroves, and water bodies. Poor soil and shortage of land on the Maldives limits agriculture (MMA, 2022). Traditional agriculture production in the Maldives is limited by poor soil, geographically split land mass limiting large scale agriculture.

Coconut is the national tree in the Maldives and a major crop which significantly contributes to food, livelihood, and the environment in Maldives. Coconut kernel is widely used in preparing of Maldivian cuisine while young coconut (kurumba) is a popular beverage, especially in the tourist resorts. Coconut products such as coir and copra had been traditionally main agricultural exports from the Maldives. Maldivian coir in the past has been exported to China, Yemen, and Persian Gulf and has extensively used in the fishing industry because of its resistance to salt water (https://archive.maldives.com/destination-guides/coir-rope-making-raa-atoll).

Maldives is blessed with an ideal climate for coconut, hot and humid weather, monsoonal rains, and more importantly high ground water availability throughout the year. Hence, there is a huge potential for large scale production and industrial development of coconut. Also, increasing population and the expansion of tourism industry as well as global potential for coconut and coconut-based products demands more coconut. Present demand for coconut in Maldives is two-fold, mature nuts for direct consumption and value-added products and immature nuts as a natural beverage. Particularly, different colour forms of dwarf coconut types such as green, yellow, red, and brown, found in many islands, are suitable for drinking. However, currently coconut is not largely a cultivated crop in Maldives. In most

of the islands it is grown as a wild plant and even cultivated no proper care and management is given. Further, census on the coconut land area, number of coconut trees and annual production in the Maldives are not available. This hinders any realistic predictions of coconut production in the country and assessments of losses due to biotic and abiotic factors. If due attention by growers and government, and facilities for rehabilitation of coconut are given, coconut could be realized as a major agricultural crop in the Maldives.

The Government of Maldives have identified several issues and constraints hampering the development of this sector. Biotic and abiotic stresses, unplanned and neglected coconut cultivation, lack of technical knowhow on palm management, input supply and training have affected increasing productivity and revitalizing of coconut industry. In addition, the lack of support services available for farming communities further worsen the existing situation. Also, it has been identified that small and large coconut growers should be organized and identify and streamline market chains along with the supply and value chain. In addition, necessary land policy changes, availability of credit and support systems, regional and international collaborations, and staff training is needed. If productivity of coconut is increased, there is a great potential to expand the coconut industry by development of coconut oil, use of coconut water, coconut timber and processing of shell and coir products etc.

Added to all these issues a severe outbreak of a fast-spreading pest and disease complex has led to significant decrease in coconut yield reported national wide and more significantly in the North of Maldives. Thus, the Government of Maldives is in the view that the current severity of the pest/disease and its spread would hinder the potential to rehabilitate the coconut plants and coconut industry. Observations of Ministry of Fisheries, Marine Resources and Agriculture indicated a complex of pests along with sooty mould fungus covering the leaves of palms and infesting other plant species including perennial fruit crops and ornamentals.

PURPOSE OF MISSION

Considering the huge potential for large scale coconut production and industrial development, the Government of Maldives has requested assistance of Food and Agriculture Organization to revitalize their coconut industry. Therefore, to address the above issues and support the Government of Maldives in managing biotic stresses, rejuvenating, and increasing productivity, and revitalizing of coconut industry in Maldives a team of three experts, Dr. L. C. P. Fernando, Biotic Stress Management Specialist, Mr. P A Henry Nimal Appuhamy, Crop Production and Technology Dissemination Expert and Dr. S.M.M. Samarakoon, Industry and Value Chain Expert were deployed by the Food and Agriculture Organization.

Terms of Reference of each consultant is as follows.

Biotic Stress Management Specialist will undertake following tasks.

- Undertake a review of the status of coconut pest and disease (P & D) prevalence in Maldives and identify present P & D management interventions and gaps in coconut biotic stress management, technologies available and possible interventions.
- Identify immediate strategies and interventions to rehabilitate affected coconut palms, and to improve overall production with strategies to improve the coconut value chain.
- Identify possible medium- and long-term technological interventions to manage current P & D issues and possible future biotic threats to Maldivian coconut industry.
- Identify the coconut supply chain deficiencies and corrective measures in Maldives and possible nodes for intervention in terms of managing biotic stresses.
- Provide technical support and primary training on coordination and managing current biotic threat.
- Provide technical advice in developing coconut nursery and mother plant management/importation of seedlings.
- Documentation and dissemination of best practices, lessons learnt and innovative methodology for farmer trainings to improve the program implementation.
- Prepare regular activity reports on field activities, results achieved along with visit reports and the final report on above aspects undertaken.
- Obtain LTO clearance on reports of the field activities and visit reports before final submission to the FAO country office.
- Perform any other duty as required.

The Agronomist (Crop Production and Technology Dissemination Expert) will undertake following tasks.

- Undertake a review of the current status and gaps in coconut production, technologies available and the potential for increasing production.
- Identify immediate strategies and agronomic interventions to rehabilitate coconut palms, increase productivity and overall production of coconut, increase total land productivity with other agriculture interventions and with strategies to improve the coconut value chain.
- Identify possible medium- and long-term technological interventions to improve productivity, production, and the potential for value addition.

- Identify the supply and value chain of coconut in Maldives and possible nodes for intervention in terms of crop husbandry.
- Provide technical support to Maldivian authorities on coordination and managing of Coconut cultivation.
- Provide technical advice in developing coconut nurseries and mother plant management / importation of seedlings for establishment.
- Documentation of best practices, lessons learnt and innovative methodologies for farmer trainings.
- Prepare regular activity reports on field activities, results achieved along with visit reports and the final report on above aspects undertaken.
- Obtain LTO clearance on reports of the field activities and visit reports before final submission to the FAO country office.
- Perform any other duty as required by the Maldivian Government in consultation with FAO.

The Supply and Value Chain Specialist will undertake following tasks under this TOR.

- Undertake a review of the status and gaps in supply and value chain, industry potential, logistics available and the potential for improvement.
- Identify possible value-added products and medium- and long-term interventions to increase revenue from the coconut industry.
- Identify and map the supply and value chain of the coconut-based industry of Maldives and identify critical nodes.
- Identify immediate strategies and interventions needed to support infusion of identified techniques in adding value to coconut industry in Maldives, with other agriculture interventions and strategies to improve the coconut value chain.
- Provide technical support to Maldivian authorities in coordination and managing of Coconut industry.
- Prepare regular activity reports on field activities, results achieved along with visit reports and the final report on above aspects undertaken.
- Obtain LTO clearance on reports of the field activities and visit reports before final submission to the FAO country office.
- Perform any other duty as required by the Maldivian Government in consultation with FAO.

Two missions to Maldives were undertaken by the consultants. The first mission was from 16 August to 06 September 2023 to assess the status of the coconut industry. The second mission from 06 – 09 November was made to present the findings, recommendations, and a strategic plan for revitalizing the

coconut industry in Maldives to the Government and stakeholders. In addition, the Biotic Stress Specialist visited Hanimaadhoo Agriculture Center from 31 October to 06 November to assist developing a parasitoid rearing programme for Rugose Spiralling Whitefly and train the officers.

REVIEW OF THE CURRENT STATUS OF COCONUT PRODUCTION, PESTS AND DISEASES AND COCONUT VALUE CHAIN IN MALDIVES

The three specialists visited several islands (Table 1) of the Maldives in their first mission to review the status of coconut production, coconut pest and disease management, and coconut supply and value chain and identify gaps, technologies available, current interventions and possible improvements necessary. Also, it was intended to recommend immediate strategies required in respect of them.

Prior to visiting islands, the specialists met with the Secretary of the Ministry of Fisheries, Marine Resources and Agriculture and Ministry officials to obtain a briefing about the coconut sector in the Maldives, issues and challenges faced and the expectations of the Government to improve the production and productivity of the sector. It was transpired that the Government is highly motivated and committed to develop the coconut sector as a profitable industry. Subsequent stakeholder meeting gave insights to some issues faced by the coconut growers. At the debriefing meeting with be Hon. Minister and Ministry officials the Minister further explained the plans of the Government in improving the coconut sector, which gave the specialists a sound understanding of the requirements.

During the field visits the specialists were able to meet with the officers of Councils, coconut growers, coconut processors and other stakeholders to further understand the field situation and related issues, problems and limitations of the coconut cultivation and processing sectors. The Biotic Stress Management Specialist made a second visit (Table 1) to assess the pest and parasitoid levels, collect more samples for identification, commence insect culture and train officers.

Table 1. Dates and places visited in the Maldives

Date	Atoll/ island
First visit	
18.08.23 – 20.08.23	L. Gan, L. Fonadhoo, L. Maandhoo, L. Baresdhoo
21.08.23 – 24.08.23	HDh. Hanimaadhoo, Ha. Kelaa, Ha. Maafahi, HDh. Finey, Sh. Goidhoo
25.08.23 – 26.08.23	Aa. Thoddoo
27.08.23 – 28.08.23	K. Kaashidhoo
29.08.23 – 30.08.23	ADh. Maamigili, ADh. Ariadhoo
31.08.23 – 02.09.23	Gn. Fuvahmulah City
03-09.23 – 05.09.23	S. Addu City (Hithadhaoo), S. Addu City (Hulhumeedhoo)
Second visit	
01.11.23 – 06.11.23	HDh. Hanimaadhoo, Ha. Kelaa, Ha. Maafahi

ASSESSMENT OF THE CURRENT STATUS OF COCONUT PRODUCTION

The Agronomist made assessment of the status of coconut cultivation in Maldives and identified gaps need to be addressed in a rehabilitation programme. It was evident that Maldives has a huge potential in increasing coconut production and productivity of coconut lands and contribute to the coconut value chain. The country already has the required natural resources such as ground water availability, ideal climatic conditions, and suitable soil, which are the most important factors for coconut cultivation. However, it was observed that the existing natural potential has not been exploited adequately due to various administrative, social, economic and attitudes of farmers and officers.

The observations disclosed that coconut production and land productivity of coconut holdings in almost all the islands are declining rapidly to a level that coconut supply is insufficient to meet the domestic requirement. In certain years, coconuts have been imported from other countries to meet the high local demand, particularly in Ramazan festival season. Although the country has the largest extent of coconut lands in many islands, the nut production and the productivity of coconut is declining rapidly due to various issues discussed below.

Specific observations of each island are given separately in Annex 1.

Prolonged negligence of coconut plantations / holdings

During the field investigations, it was very clear that the management of coconut plantations/ holdings has been neglected badly for many years due to various social and economic reasons. As these cultivations are not productive and profitable, the owners have completely neglected the managing the land for years. The major reason being the lack of basic understanding on agronomic requirements of the coconut palm. Hence, mistakes at the initial planting stage are very difficult to be corrected at the latter stage. The rehabilitation of neglected plantation involves thinning out of excess palms to maintain the desired palm density. However, farmers are not prepared to rehabilitate their plantations in this manner as they have no confidence and interest in the process which involves cost and time.

Most of the coconut holdings owned and managed by the councils and large plantations located in uninhabited islands have also been neglected for many years. The coconut plantation located in Baresdhoo, Ariadhoo and Maandhoo are some examples. The present management and productivity levels of these plantations are highly unsatisfactory.

Coconut palm, being a perennial tree is highly sensitive to agronomic management practices. Due to prolonged negligence palm would reach a stage where nut production reaches to a minimum level and deteriorating of its growth that is beyond recovery. The situations of coconut plantations/ holdings which have been neglected for many years created undesirable environment as highlighted below.

a. Thick undergrowth of natural weeds, shrubs, trees, and different vegetation within the coconut avenues have created an unreachable ground situation. This has led to a jungle-like situation within the coconut plantation preventing the collection of fallen nuts and carryout routine plantation management practices.

b. In the absence of frequent nut picking (harvesting) system, the collection of fallen nuts is the only way that owners receive income. But the messy ground situation due to thick growth of vegetation, minimizes the collection of fallen nuts.

c. Under the situation where majority of fallen nuts are not collected nuts have germinated around mature palms forming clusters of seedlings and young palms, which have aggravated the untidy ground condition within the plantation.

d. The health and the productivity of mature palms in this condition deteriorate severely due to very high root completion, depletion of soil nutrients, yellowing of leaves owing to nutrient deficiencies and water stress symptoms during dry periods.

e. Increased rat damage to both young and mature nuts occur due to existence of favourable breeding grounds within the plantation.

f. High level of thieving and security alerts

According to the observations, neglected coconut holdings could be categorized as follows.

a. Large coconut plantations found in uninhabited islands, which were established about 40 - 50 years ago by using correct planting distance and densities mainly with imported planting materials. The neglected coconut plantation located in the Baresdhoo, Ariadhoo and Maandhoo islands require an urgent rehabilitation program.
b. The neglected coconut holdings owned by the councils of different islands.
c. Neglected coconut palms in house holdings and lands allocated for cultivation of vegetable and fruits.
d. Neglected coconut palms planted in roadsides in islands where agricultural lands are limited.
e. Neglected coconut holdings along the coastal areas to provide shade.

Poor management and technology gaps

One main problem in coconut cultivation in the Maldives is poor/ no management of coconut plantations. It was observed that the cultivation and management of existing coconut lands are not given due recognition and priority in on-going agricultural development projects carried out by island councils. The use of coconut cultivation and management technologies at the farmer level is highly unsatisfactorily. One reason for this is lack of technology dissemination, training, advisory and farmer support services available at the grassroot level. Farmers and officials are highly lacking in technical knowledge on basic biological and agronomic requirements of coconut palms. Extensive research and long-term experience in other coconut growing countries have shown that practicing appropriate cultural and agronomic management practices, such as use of certified planting material, planting at correct density, enhancing soil fertility, and managing biotic and abiotic stresses are essential to increase coconut production to its maximum potential.

Large- and small-scale farmers and council officials are highly interested in developing coconut cultivation and increasing its profitability. It is accepted that there is no access to required technology, planting materials, advisory and farmer support services to rehabilitate plantations. Under the present administrative setup of councils, coconut development activities are given insufficient priority for technology dissemination, promoting technology adoption, farmer training, advisory and support services. Coconut farmers have no access to technical guidelines on coconut planting and management of seedlings and young palms.

High palm density and overcrowded coconut plantations

Cultivation of coconut at close distance to each other (high density) was found to be the biggest limiting factor for declining nut production. High-density coconut plantations would eventually lead to empty crowns without nuts and inflorescences. Heavily overlapping fronds creates high competition among palms for sunlight, plant nutrients and water. Prolonged negligence of most plantations has brought about disordered ground conditions covering the plantations with large trees, thick growth of shrubs, weeds, and fallen coconut fronds. Due to this physical barrier collection of mature fallen nuts has become impossible in some areas resulting in many naturally germinated nuts and seedlings in different ages under mature palms forming a crowded jungle like situation. This condition could be regarded as a full waste of valuable resources, which must be addressed with immediate interventions. It was observed that even at present, coconut seedlings issued to people are planted at very close distance in their holdings without any concern on the minimum planting distance between palms. Council officials and farmers are not aware of the correct distance of growing palms. This is mainly due to lack of their technical knowledge regarding the basic agronomic requirements of coconut palm. Even in households

coconut is cultivated at close distance resulting palms with low nut yield due to mutual competition and overcrowding. However, in some households coconut palms are growing in accepted distance with vegetables and fruit plants and are bearing very well.

Root competition and plant nutrient deficiencies

In high density coconut plantations, it was prominent that coconut leaves have turned yellow due to deficiencies of major plant nutrients (Nitrogen, Potassium, Phosphorus and Magnesium). In Maldives, fertilizing of coconut palms is rarely practiced. Non application of chemical or organic fertilizers, high root completion among other trees and palms and rapid deterioration of soil nutrient status are major contributory factors for low nut yield. However, it was found that some innovative farmers have been able to increase nut production by about three-fold by application of fish meal and organic matter. Some growers prefer application of poultry manure. It was observed that in some islands coconut is cultivated along the boundary of vegetable plots and because of the fertilizer and water applied to vegetables, coconut palms have benefited indirectly resulting in high yielding healthy palms. But some farmers have cut and removed coconut fronds excessively to provide more sunlight for their vegetable cultivations without knowing that removal of fronds adversely affect the palm growth and nut production.

Fully neglected coconut plantation

Young coconut holding with low nut yield

Undergrowth with naturally germinated seedlings

Overlapping fronds in close distance planting, with empty crowns

Lack of high-quality planting material

At present there are no coconut nurseries maintained either by the ministry or councils to fulfil the seedling requirements for planting programs. In Baresdhoo island a coconut nursery is maintained with germinated nuts collected from their own plantation, however the growth level and the method of establishment of the nursery was highly unsatisfactory. Coconut seedlings imported from India has been distributed for planting in households, council owned lands and roadsides in many islands. Although, there are high bearing palms and palms with different colour forms available in islands, which are suitable for production of mature nuts and beverage purposes, no attempt has been made to use their nuts as planting material.

Effect of land use policy

In coconut growing islands, owing to land scarcity, the full authority of lands comes under the responsibility of respective councils. Blocks of lands are issued to people for housing and farming for a short period. Other lands with coconut holdings are owned by the councils. However, majority of these holdings are badly neglected for many years without making a reasonable revenue. Residents are allowed to collect fallen coconuts from the council owned areas, free of charge or at a nominal charge for their own consumption and other purposes. In this condition, neither residents in the area nor the council show interest to rehabilitate the coconut palms. It is worth investigating the reasons why the respective councils or people in the area have allowed such a waste of valuable resources without making any development effects. In some other islands, blocks of fertile land are leased out to people

for the cultivation of vegetables and fruits for a short period. Although they are interested in cultivating coconut along with vegetable and fruit trees, the short leasing period discourages them from planting coconut as it requires more than five years to provide a reasonable income. It was observed that at present, in many islands, large extent of coconut lands has been neglected for many years without making the best use of fertile soil and other resources.

Attitudes of farmers

The general attitude of farmers and people is that coconut is a plant that does not need any care or management and could be grown and produce nuts by itself. This is because of their experience in seeing coconut palms doing well and produce nuts due to rich natural resources prevailing in the Maldives. However, they do not realize that soil nutrients deplete over time along with insufficient inputs and management leading to gradual deterioration. As the coconut sector is now in crisis since most coconut holdings are not productive enough and not generating reasonable revenue, some growers and officers have negative attitudes on the cultivation and rehabilitation of existing plantations. As these attitudes create a negative impact over the sector development programs, farmer participatory field demonstrations could be carried out to change the attitudes of farmers and officers. In addition, well planned social intervention programs could also be conducted for changing these attitudes.

PROPOSED IMMEDIATE AGRONOMIC INTERVENTIONS

While the gaps identified above must be addressed in short-, medium- and long-term basis, the immediate actions proposed are given below.

Preparation of a scientific coconut technology guide

During the field observations and discussions with of farmers and officials it was realized that the basic agronomic and biological requirements of coconut palm are not known to them. It would be impossible to implement the proposed rehabilitation and sector development programs to achieve the expected outputs without proper technical knowledge on coconut. Therefore, it is essential to prepare a comprehensive “Coconut Technology Guide” with scientific details based on the prevailing issues and limitations in the coconut sector. The officials and farmers could then follow these technical guidelines in field level implementation of programs. The proposed technology guide may include information on the following aspects.

- Details of available planting material for field planting
- Selection of suitable planting material for field planting
- Selection of suitable place for planting of seedlings

- Details of minimum planting distance and planting systems
- Suitable palm density per hectare/acre
- Methods of marking planting holes
- Preparation of planting hole for planting a seedling
- Correct field planting of seedlings
- Application of fertilizer and organic manure for seedlings and young palms
- Identification of coconut pests and diseases and their preventive and control measures
- Protection of seedlings, young and bearing palms from pests and diseases
- Application of water to seedlings and young palms during dry periods
- Mulching manure circle of young and mature palms with organic materials
- Major plant nutrient requirements and their roles
- Identification of plant nutrient deficiency symptoms and corrective measures
- Fertilizer and organic manure recommendations, application methods, and frequency for bearing mature palms.
- Management of weeds in coconut growing areas.
- Method of removing existing mature palms in neglected and high-density mature plantations as the first stop in rehabilitation projects.
- The production process of compost and organic fertilizer with available plant and animal materials
- Picking and collection of mature and immature nuts for sale
- Assessment of agronomical limitations of coconut growing soils (soil pH, soil organic and nutrient content, soil depth, ground water level, soil drainage and water logging)
- Method of enriching soil fertility levels with organic material supplemented with essential plant nutrients.
- Agronomic guidelines to be considered in establishing coconut based integrated farming systems with vegetable and fruits.
- Integration of poultry and goad farming into the existing coconut system.

Technology dissemination and training of trainers and farmers

In addition to the above technical areas, the technology guide should also include methods to enhance social acceptability and economic aspects of coconut cultivation. The technology dissemination and promotion strategies, training of trainers and farmers, establishment of farmer-based field demonstrations, farmer field school approaches, field training programs and impact assessment at the field level should also be included.

Based on the coconut development priorities identified at the Ministerial level to achieve the expected targets in terms of coconut production, productivity, and profitability, an internal (ministerial and council level) organizational structure needs to be developed to ensure the dissemination of technologies to the grassroot level in each island. At the council level, one or two trained persons could be assigned to undertake coconut development tasks at the farmer level. After achieving their technical proficiency levels by training, they could be appointed as Field Extension Officers for the coconut sector in different islands.

These officers must also be trained to produce required printed material, use of social medias and different media flatforms, production of television and radio programs, farmer group completions, establishment of a telephone hotline for information and farmer support services. Video documentaries on field success stories also be produced and used in training programs to convince the participants.

Development activities

As an immediate strategy to increase nut production and land productivity, early rehabilitation projects could be initiated in the following large plantations.

Coconut plantation in Baresdhoo island

The Government own companies AgroNat and Maldivian Integrated Tourism Development Corporation (MITDC) presently manage this plantation. The coconut plantation of about 75 ha. covers the entire island. It was originally established with the tall variety of palms imported from Malaysia. The size of the mature nut is large, and the husked nut weight is also high. The 30 - 35 years old plantation is planted in square planting system of 25'x 25', which is acceptable for a commercial cultivation. However, at present, the entire plantation is not managed well resulting in heavily grown shrubs, trees, weeds in coconut avenues which prevent complete access to the plantation and even minimize fallen nut collection. Many fallen nuts are germinated and grown wild at different heights forming a thick jungle with other trees in between coconut rows. All palms are subjected to very high competition with surrounding coconut seedlings and other deep-rooted trees and shrubs, which has resulted in low nut yield and waste of valuable resources. Almost all mature palms show acute deficiency symptoms of major plant nutrients (N, P, K, Mg) leading to yellowing of coconut fronds with scorching leaf tips. As these palms are highly under stress, they are susceptible to pests and disease incidence. Rats damage high percentage of mature and immature nuts due to untidy ground management.

With a suitable package of technologies, early action should be taken to clear the undergrowth in coconut avenues and implement palm rehabilitation activities with a manageable action plan. There are several issues to be addressed and if necessary, priority is given, the entire plantation could be rehabilitated within 2 – 3 years. During this period, nut production and overall productivity of the plantation could be enhanced to a profitable level.

Coconut plantation in Ariadhoo island

This is an uninhabited island with a large coconut plantation which was planted about 40 - 45 years ago with correct distance. Presently, the plantation is managed by the Ministry of Fisheries, Marine Resources and Agriculture. The plantation has a long history and person who established the coconut plantation has followed correct management technologies and developed it as a coconut based integrated farming system with buildings, structures, and irrigation systems and even with green houses. However, the entire plantation is badly neglected for years and resulted in a jungle-like situation with wildly grown coconut undergrowth, other large trees, shrubs, and thick weed growth. Almost all the palms in the plantation are under severe stress due to lack of management and root competition from undergrowth.

The overall production and the productivity of this plantation could be increased within a short period, with a suitable package of technologies and properly planed implementation schedule.

Coconut plantation in Maandhoo island

This coconut plantation is managed by the Horizon Fisheries Company at the Maandhoo Fisheries Complex. They manage two separate coconut plantations. One is 70 ha located opposite side of the factory complex and other one is at the factory complex which is about 15 hectors. Mature plantation is about 45 -50 years old, planted with about 24’ x 24’ square planting system with a coconut variety imported from Malaysia. Clearing work of the larger plantation is underway by removing shrubs and trees which is essential to reduce root competition. However, very large extent of the plantation is completely neglected for years resulting in a jungle like situation. Wildly grown coconut clusters, trees, large shrubs, and thick weed growth are in coconut avenues.

Immediate action should be taken to rehabilitate the plantation with a complete technology package and a well-planned implementation strategy. The overall nut production and land productivity could be enhanced two-fold within a 2 -3-year period.

ASSESSMENT OF THE CURRENT STATUS OF PESTS AND DISEASES

The biotic stress management specialist visited several islands to identify and assess the status of the fast-spreading pest in coconut. In the same visit the specialist assessed the other pest and disease status too. Coconut leaf samples representing the total coconut area of each island was collected for examination of the level of infestation of the new pest species. Insects were collected for taxonomic identification.

Identification and assessment of the new pest species spreading on coconut palms

The observations revealed that the pest currently infesting coconut palms in Maldives is a whitefly insect. Two types of morphologically different whitefly adults were observed coexisting on infested coconut leaves. The damage of whitefly was observed on all ages of coconut palms, and it was confined to lower whorl of fronds and spreading to middle and upper fronds, with the severity of infestation. It was observed that infestation was more severe in King coconut palms and yellow colour coconut varieties. It was also more on isolated palms in open areas and roadsides. Whiteflies excrete a thick sugary substance called honey dew, which provides an excellent substrate for growth of mould. The black colour sooty mould was seen covering infested coconut leaves. Sooty mould is not a new disease of coconut as the farmers of Maldives speculated, but a secondary cause of whitefly infestation.

Whitefly species are major pests of coconut as well as many other field and horticultural crops and ornamental plants worldwide. They cause a substantial damage and economic loss to susceptible crops. Both young and adult stages of the whitefly suck the sap of plant tissue and while feeding, excrete honey dew which promotes sooty mould on leaves and fruits leading to adverse effects on crop productivity.

According to the observations on the damage whitefly infestation has been in various degrees from mild to severe in the islands where it was present. Currently, the infestation is largely subsided in almost all localities visited. In those localities whitefly colonies are dislodged/ washed off and only the damage on leaves (yellow patches) were seen. Sooty mould has been dislodged largely leaving only the damage signs.

However, in some localities, re-infestation has started, mostly on the same palms previously infested and on some new palms. The assessment report of each island is given in Appendix 1.

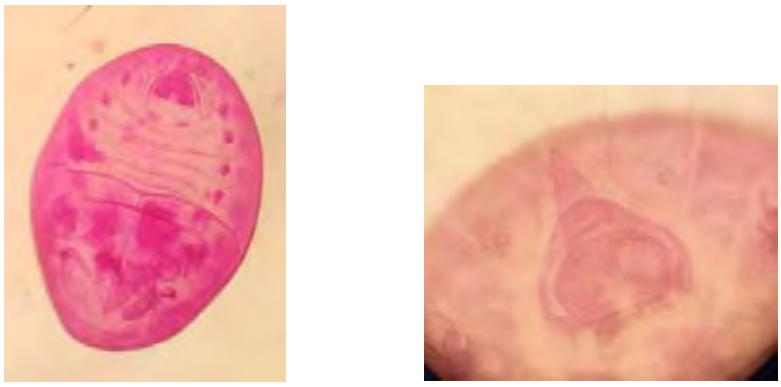
For identification and detailed assessment of the currently spreading pest/disease complex samples of affected coconut leaflets were collected from coconut trees from different locations in each island to

represent the total coconut growing area of the island. Each leaflet was examined for different stages of the pest and their natural enemies. Puparia were collected and preserved for subsequent identification of pest species.

Taxonomic identification of the specific species

The preserved specimens were identified at laboratory of the Coconut Research Institute of Sri Lanka. Permanent microscope slides of whitefly pupal cases were prepared following the method described by Sirisena *et al*. (2015) with few modifications. Whitefly species were identified taxonomically by studying the morphological characteristics of slide-mounted-pupa using standard taxonomical keys (Martin 1987; Martin *et al.,* 2000; Hidaya *et al*. 2018).

The predominant whitefly species found in samples collected from all locations in Maldives was confirmed as *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), commonly known as Rugose Spiraling Whitefly (RSW). The slide mounted specimen of *A. rugioperculatus* and its lingula is shown in Fig. 1. *A. rugioperculatus* has not been reported in Maldives and this is the first record of its presence.

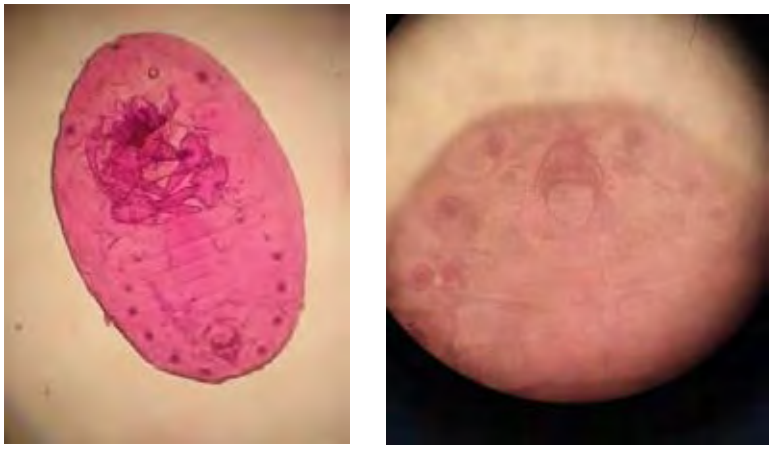


A B

Figure 1. Slide mounted specimen of A). *A. rugioperculatus* pseudopupae, B). close up of operculum and lingula

The other whitefly species was taxonomically identified as *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae), commonly known as Bondar's Nesting Whitefly (BNW). Its' slide mounted specimen and the lingula is shown in Fig. 2. *P. bondari* has not been reported in Maldives before, hence this is its first record in the country.

RSW (Fig. 3A) is larger than BNW (Fig. 3B) and both species coexist on the leaves (Fig. 3C).



A B

Figure 2. Slide mounted specimen of A). *P. bondari* pseudopupae, B). close up of operculum and lingula

A B C

Figure 3. A) Rugose Spiraling Whitefly, B) Bondar's Nesting Whitefly C) Coexistence of RSW and BNW

Rugose Spiraling Whitefly, A. rugioperculatus

A. rugioperculatus first reported from Florida, United States of America in 2004 (Martin, 2004) is distributed in 22 countries in Central and North America (Evans, 2008) and invaded India in 2016 (Selvaraj *et al*., 2016; Shanas *et al*., 2016, Karthick, 2018), Bangladesh (Dutta *et al*., 2019) and Sri Lanka in 2019 (Aratchige, 2022). *A. rugioperculatus* has been classified as a serious threat to coconut palms (Stocks and Hodges 2012). It is a highly polyphagous species with large number of alternate host plants (Francis *et al*., 2016, Shanas *et al.*, 2016; Selvaraj et *al.*, 2017; Khan, 2022).

Biology

Rugose spiralling whitefly adults can be distinguished by their large size and the presence of a pair of irregular light brown bands across the wings (Fig. 2A) (Stocks and Hodges, 2012). Adults are about

three times larger (approx. 2.5 mm) than the commonly found whiteflies and are lethargic by nature. Males have long pincer-like structures at the end of their abdomen. Females lay eggs on the underside of leaves in a concentric circular or spiral pattern and cover it with white waxy matter (Fig. 4). Eggs are elliptical and yellowish in colour, 0.3 mm long, translucent with a short stalk and are laid singly and associated with irregularly spiralling deposits of white flocculent wax surrounding each egg in a semi-circular spiralling fashion. RSW has five developmental stages. The first instar, known as the crawler stage (because it is the only mobile immature stage) hatches out of the egg, and looks for a place to begin feeding with its needle-like mouth parts and sucks plant sap. Crawlers moult into immature stages that are immobile, oval and flat initially but become more convex with the progression of its life cycle (Mannion, 2010). Nymphs are about 1.1 - 1.5 mm long but may vary in size depending on instars (Fig. 5). The nymphs are light to golden yellow in colour, and produce a dense, cottony wax as well as long, thin waxy filaments (Stocks and Hodges 2012) which get denser over time. The final immature stage is the pseudo-puparium, which is used in taxonomic identification. (Fig. 6). The development time of *A. rugioperculatus* is reported to vary on different host plants and environmental factors. On coconut, egg to adult emergence takes about 37 days. Adults emerge from pupa through a 'T' shape exit hole and live about 20 days (Saranya *et al*., 2021).

RSW colonizes the lower surface of leaves and both adults and nymphs feed on the leaves (Fig. 7). The nymphs secrete a heavy white, waxy material which is characteristic of whitefly. Several colonies with different stages of whiteflies could be observed within these cottony, white structures.

Figure 4. Egg spirals of RSW

Figure 5. Nymphs of RSW

Figure 6. Puparia of RSW

Figure 7. Colony of RSW

Bondar's Nesting Whitefly, P. bondari

P. bondari was first described on citrus species from Brazil in 1971 (Peracchi, 1971). Since then it has spread to North and South America, Africa and Asia and has a wide range of host plants [(*Paraleyrodes bondari)* CABI Compendium (cabidigitallibrary.org)]. In India, it was first reported in 2018 (Chandrika *et al*., 2019).

Biology

The adult is a small fly measuring about 1.0 mm with a dull yellow body and possesses 'X'-shaped oblique greyish markings on forewings (Sankarganesh and Roy, 2021) (see Fig. 3B). The colony of *P. bondari* is characteristic of short filaments and nest like structures (Fig. 8). They construct this unique woolly wax nests on the abaxial surface of leaves. A female lays eggs ranging from 36 to 75. The eggs are stalked, clustered eggs and hatches into first instar crawler, which finds a feeding site and settle. Crawlers are active, mobile, oval, and translucent with hyaline fringe of wax filaments along the lateral margin. Second and third nymphal instars are immobile and have a pair of yellow spots below the midline of the body. The nymphs are creamy yellow and transparent with the presence of marginal hairs (Fig. 9). Total nymphal development period is 13 -16 days. The pupa is flat with a characteristic pattern of wax around (Sujithra *et al*., 2019).

Nature of damage and symptoms of RSW and BNW

At the initial stage of the infestation, small circular yellow colour spots appear on coconut leaflets and later turn into large, yellow colour, irregular shaped patches (Fig. 10). Besides, RSW excretes a sticky, glistening liquid substance (honeydew), turns into a viscous liquid which provides an excellent substrate for growth of sooty moulds (Fig. 11). Once it dries, the sooty mould forms thick layers on the leaves and undergrown plant surfaces. The layers of sooty mould on leaves may disrupt the photosynthesis

process in the host leading to physiological disorders. Honeydew also attracts ants and wasps that protect the whiteflies from their natural enemies (Stocks and Hodges 2012). In addition to damaging its host, RWF whitefly also creates a nuisance to human beings in the area of infestation. Honeydew, sticky wax, sooty mould and waxy flocculent material deposited on the understory plants and non-plant surfaces such as automobiles, patios, and furniture. With the progression of the infestation many colonies develop on leaves which is seen as white encrustations (Fig. 12). The leaves gradually dry off and severely damaged trees show a burnt like appearance (Fig. 13).

Figure 8. BNW inside waxy nest

Figure 9. Nymphs of BNW

Presence of natural enemies

In samples collected from the field, pupal cases with parasitoid emergence holes were observed (Fig. 14). Also, there were a high proportion of parasitized pseudopupa, which are black in colour (Fig. 15). The presence of parasitism was observed in all locations sampled during the visit. The parasitoids emerged from the parasitized pupa was identified as *Encarsia guadaloupe* (Hymenoptera: Aphelinidae) at the laboratory of the Coconut Research Institute (Fig. 16). It was revealed that the parasitism levels are increasing, particularly in Kella, Hanimaadhoo and Mafahi where sampling was carried out for the second time, about 2 months after the first sampling. Over 50% of parasitism was observed in the samples, but less in Mafahi.

Some coccinellid beetles were found associated with the whitefly colonies, but their predation on whitefly was not determined.

Figure 10. Damage patches on leaves

Figure 11. Sooty mould growth on leaves

Figure 12. RSW colonies on lower leaf surface

Figure 13. Severely infested trees

Figure 15. Parasitized puparia of RSW

Figure 14. Parasitoid emergence holes on puparia

Figure 16. *Encarsia guadeloupe*

Other pests and diseases of coconut

Other notable pest damages observed were due to hispid beetle, *Brontispa longisimma*, *Oryctes* beetle, *Oryctes rhinoceros* and rats.

Coconut Hispid beetle (*Brontispa lingissima*) Gestro (Coleoptera: Chrysomalidae**)**

In Maldives, the hispid beetle has been first noticed in December 1999 in Sun Island resort in South Ari Atoll. It was reported to the Ministry of Fisheries, Agriculture and Marine Resources in early 2000 (Shafia, 2004), it has since known to spread to several neighbouring islands. The survey carried out in 2003 confirmed that the beetle had spread from the known distribution range (Fenfushi, Tholhufushi, Nalaguraidhoo, Dhiffushi, Maamigili and Ariyadhoo) to islands further eastwards Dhidhdhoo and Dhidhoofinolu and Dhigurah. The survey also confirmed that the beetle had not spread to the northern parts of the atoll and southern Ari atoll at the time.

According to the current assessment, the hispid beetle damage status in different Atolls is given in Table 2. Low, moderate, and severe damages refer to less than 10%,10% - 40% and more than 40% leaf damage respectively. However, the damage level was not similar in all the palms in an island but varies largely. Hence, the damage level given is a general status of each island.

Oryctes beetle, *Oryctes rhinoceros* (Coleoptera: Scarabeidae)

O. rhinoceros is endemic to the coconut-growing regions of South and South-East Asia from Pakistan to the Philippines (CIE, 1967), including Maldives.

The current observation revealed that the pest is distributed in all the areas visited. The damage is mainly seen in seedlings and young palms. Throughout Maldives the damage is low, only having less than 10 leaves damaged. Hence, it could be considered as not having significant and economic impact on growth and yield of palms. Also, the damage level varied largely within an island. Table 3 gives the incidence of damage in different islands.

Rats

Rat damage was reported from several islands varying in severity across islands. It was observed that forest areas close to coconut palms and poor sanitation conditions in the vicinity favours breeding of rats.

Other minor pests

In most locations mild infestation of coconut scale insects was observed, especially on the same palms where whitefly damage is present. But their damage was not significant.

Coconut mite damage was seen on young and mature coconuts on some locations. Its incidence was extremely low and currently non-significant. The mite species inflicting the damage cannot be determined exactly by the symptoms present.

Few incidences of mealy bugs were observed in some areas, but they were in extremely low numbers and on very few palms.

No disease incidences or damages were observed in any area visited.

Table 2. Damage level of hispid beetle on coconut palms

Atoll/ Island/ Council area	Damage level
L. Gan	Low
L. Baresdhoo	Moderate
L. Maandhoo	Moderate
L. Fonadhoo	Moderate
HDh. Hanimaadhoo	Moderate
Ha. Kelaa	Moderate - Severe
Ha. Maafahi	Moderate - Severe
HDh. Finey	Moderate
Sh. Goidhoo	Nil
Aa. Thoddoo	Nil
K. Kaashidhoo	Nil
ADh. Maamigili	Nil
ADh. Ariadhoo	Nil
Gn. Fuvahmulah City	Nil
Addu City (Hithadhaoo), S. Addu City (Hulhumeedhoo)	Nil

Table 3. Indicence of Oryctes beetle damage on coconut palms

Atoll/ Island/ Council area	Damage level, remarks
L. Gan	Low (In many sites poor sanitation was found favoring breeding of the beetle).
L. Baresdhoo	Low
L. Maandhoo	Low
L. Fonadhoo	Low
HDh. Hanimaadhoo	Low
Ha. Kelaa	Low
Ha. Maafahi	Low (Damage was observed close to the composting heap. Pheromone-baited traps for the have been installed)
HDh. Finey	Low
Sh. Goidhoo	Low
Aa. Thoddoo	Low
K. Kaashidhoo	Low
ADh. Maamigili	Low
ADh. Ariadhoo	Low
Gn. Fuvahmulah City	Low
Addu City (Hithadhaoo), S. Addu City (Hulhumeedhoo)	Low-Moderate

PEST MANAGEMENT INTERVENTIONS IN MALDIVES

Pests and diseases pose a threat to agricultural crop plants by affecting their growth, reduction in yield and even death of plants. A large number of pests and diseases have been reported on coconut worldwide, some being indigenous to the countries, and some introduced. Introduced pests/ diseases often outbreak and become invasive due to absence of their natural enemies in the invaded country. Incidences of indigenous pests/diseases too vary over time, mainly with the climatic conditions and presence of other favourable habitats for their breeding. Therefore, it is essential to formulate and implement management strategies and carry out risk mitigation measures to safeguard coconut palms.

In Maldives, *Oryctes rhinoceros* and rats were recorded as indigenous pests of coconut. Hispid beetle (*B. longisimma*), nettle caterpillar (*Darna nararia*) and recent outbreak of whitefly (*A. rugioperculatus* and *P. bondari*) are the major introduced pests. *D. nararia* that was confined to Maandhoo was successfully contained and managed by insecticidal treatment and naturally occurring parasitoids.

No disease incidence of coconut has been reported or observed.

Rugose spiralling whitefly

According to the Ministry of Fisheries, Marine Resources and Agriculture two species of whiteflies, *Aleurodicus disperses* and *Bemisia tabaci* has been reported in Maldives in1980's. The parasitoid, *Encarsia* sp. has been imported and released during 1990s to manage the whiteflies.

In 2020 – 2023 exotic whitefly species has been observed spreading in coconut and has become an outbreak in 2022 - 2023 period causing yield losses as indicated by Ministry officials. The Government of Maldives have taken several steps to manage the pest. The Ministry of Fisheries, Marine Resources and Agriculture has recommended spraying of 1% neem oil and soap mixture to affected palms. Some Councils have sprayed the mixture in a small proportion of palms and found successful. However, due to failure in spraying repeatedly, those palms have been reinfested. Further, due to the tall nature of palms and difficulty in accessing palms in jungle areas this operation has not been carried out widely. The Ministry has imported a commercially available fungus, *Beuveria bassianna* from India and distributed to Councils to spray on affected palms. But due to the difficulties in application its use was not reported.

Considering the fast-spreading nature of the pest, the Government of Maldives have sought assistance of the Food and Agriculture Organization to identify the whitefly species inflicting damage and to implement management strategies.

Hispid beetle

It was noted that hispid beetle has been accidently introduced to Sun Island with ornamental palms imported from nurseries in Malaysia and Indonesia in 1999 (Shafia, 2004).

Sun Island resort management has implemented chemical control measures including cutting of infested leaf spears and application of the insecticide, Carbamate ('Sevin') to central crown and injection of systemic insecticide (Monocrotophos) into the trunk of infested trees. In addition, recommendations were made to remove and burn seedlings. In other areas until a biological control agent is introduced,

placing of bags containing 10g. of Diazinon 10% granules in bases of unopened leaves has been recommended. The product is known to be more effective for coconut hispid beetle.

Considering the risk of rapid spread of the pest, its possible damage and failures of attempted control measures, the Government has sought assistance of the FAO. Hence, a project has been launched in 2003 with two experts and local counterparts for the ecologically friendly management, focussing on biological control.

The parasitoid, *Asecodes hispinarum* has been imported from Vietnam in 2003 and mass bred in a laboratory in Sun Island. Nearly 300,000 parasitoids have been released in the locations the pest was reported in 2004. According to the preliminary assessments it has been found that *A. hispinarum* is established in the field, although parasitism levels were low soon after releases. (Shafia, 2004). Data collected from the sun island after four months of parasitoid release indicated very low parasitism (less than 3%) while in other islands it was nil. Further studies conducted in September 2004, revealed that the parasitism level is increasing. However, parasitoid establishment on the inhabited islands of Maamigili and Fenfushi has not been satisfactory, despite the release of large numbers of adult parasitoids and mummies on both islands.

In addition, several other steps have been implemented in managing the hispid beetle. Awareness programmes among the local population have been conducted by radio broadcasts on the threat of the coconut hispid beetle, television programmes to inform people about the pest status in the country, posters containing information on the pest have contributed significantly to increase public awareness on the pest. The quarantine regulation was imposed by prohibiting inter island movement of fresh coconut leaves/fronds, mature coconut palms and coconut seedlings from a *Brontispa* infested island. *Brontispa* reporting mechanism and training of trainer programmes were established (Shafia, 2004).

Chinese Academy of Tropical Agricultural Science (CATAS) has supported Maldives to introduce and mass produce parasitoids in Maldives [Coconut Pest Management Cooperation between China and Maldives (china-embassy.gov.cn)]. In May 2015, a biological control laboratory has been set up in Maldives and began to produce *Asecodes hispinarum* and *Tetrastichus brontispae* and over 1.5 million parasitoids have been released in field coconut to suppress the pest population. Further details of this programme are not available.

It was understood that the Ministry of Fisheries, Marine Resources and Agriculture has established a parasitoid rearing laboratory in their Quarantine Unit, but production of parasitoids has not been continued.

Oryctes beetle

It is reported that infected beetles infected with the Baculo Virus strain xx and xy have been released in the Maldives in 1984 to control *Oryctes* beetle (Zelazny *et al*., 1992; In. leaflet prepared by Anusha Vithana, Ministry of Fisheries, Marine Resources and Agriculture). No other literature on management strategies was found.

Rats

Although rat damage is widespread in the islands, undertaking of any control measures was not observed, except in Maafahi island. In this island cleaning of coconut crowns, placing baits in crown and on ground are undertaken. Rats are continuously trapped in the baits with no considerable reduction of population. This is mainly because of the suitable breeding grounds (forest boundary) available in the plantation. In addition, metal bands have been installed around the palm trunks to prevent rats walking up the trunk.

EFFECT OF PEST DAMAGE ON VALUE CHAIN OF COCONUT

Pests of coconut inflict damage to different parts of the coconut palm. In Maldives, hispid beetle, Whitefly and *Oryctes* beetle damage the leaves. Although, these damages have no direct effect on nut production, it indirectly affects the production due to reduction in leaf area available for the plant to produce food for its maintenance and nut production. Rat damage to nuts contributes to nut loss. Although, low amount of leaf damage could be tolerated and compensated by coconut palms, yield losses occur by damage beyond that. In Maldives combined effect of all these damages has led to certain level of crop loss, even though not estimated. The direct loss of nuts as well as reduced nut production due to pest damages affect the supply chain of coconut by deficient in supplying potential number of nuts.

GAPS IN PEST MANAGEMENT

Out of the major coconut pests reported in Maldives, Hispid beetle and Whitefly are introduced to the country. The Nettle caterpillar (*Darna nararia*) reported in mid-1990's was also an introduced pest, but it was controlled successfully. It has been reported that Hispid beetle was introduced to the country through ornamental palms imported from nurseries in Malaysia and Indonesia. Similarly, it was speculated that Nettle caterpillar was introduced to Maandhoo through coconut seedlings imported from Malaysia. Such a mode of introduction is possible for whitefly too. These accidental introductions point

to the gaps in the present quarantine system of Maldives. Absence of a Pest Risk Analysis before importation, strict phytosanitary conditions and lack of post quarantine facilities is a major gap in the current plant quarantine system.

It was noted that the government takes suitable action to manage introduced pests whenever they outbreak. But these actions are taken for a short period of time and continuity of those actions are lacking, especially after the project period. An example of this is biological control of Hispid beetle. Although, effective parasitoids were imported and released, releases have not been continued. Sufficient effort has not been taken to mass breed the parasitoids in the country to enable inundative releases until successful control is achieved. This is same with the release of virus infected beetles for the control of *Oryctes* beetle. Combined with this is the lack of a proper pest monitoring mechanism.

It was evident that there is no trained staff or staff assigned to carry out pest management activities in coconut. Now that responsibility of pest management lies with individual councils, there are no officers who is competent enough to monitor and carry out management strategies for pests. Due to this fact the management strategies initiated could not be continued and monitored effectively. This is a serious gap in pest management activities in Maldives.

Currently, Maldives has no laboratory facilities (except in Plant Quarantine Unit) to carry out basic entomological studies and pest management activities such as mass breeding of natural enemies.

Most people in the islands are not aware of the pest damages and how they could be managed. Since there is no effective information dissemination and awareness programmes for public it would be difficult to get their participation and involvement in pest management activities. Similarly, the officers lack sufficient knowledge in pest management methods.

MANAGEMENT TECHNOLOGIES AVAILABLE FOR COCONUT PESTS

Since the coconut pests observed in Maldives are prevalent in other countries, various management strategies are available, mostly focussing on integrated methods with priority on biological control.

Rugose Spiralling whitefly (RSW) and Bondars'Nesting Whitefly (BNW)

Mechanical, chemical and biological control methods are known for management of RSW.

Central Plantation Crop Research Institute of India has recommended use of yellow sticky traps to trap the adult whiteflies (CPCRI). In Sri Lanka, yellow sticky bands placed around trunks of palms was effective in trapping whitefly adults as they are attracted to yellow colour (Aratchige, 2022).

Both India and Sri Lanka have recommended judicious use of chemicals. Spraying of 0.5% neem oil was recommended in India in case of severe infestation. Spraying starch solution (1%) to dislodge the heavy sooty mould deposition on the leaves of infested plants is also recommended in India (CPCRI; Rao *et al*., 2018). Spraying of Thiomethoxam (3g in 10 l), Carbosulfan 200 g/l SC (20ml in 10 l) and Chlorantraniliprole 20% +Thiamethoxam 20% (2.5g in 10 l) and neem oil (10g) and soap (5g) in 1 l of water were found to be effective in controlling the whitefly up to 89% in Sri Lanka. However, the synthetic insecticides are recommended only to newly infested areas and coconut nurseries, while neem oil-based insecticide is recommended to any infested area to safeguard the build-up of natural enemies (Aratchige *et al*., 2023).

Several natural enemies of RSW have been reported. Taravati *et al.* (2013) and Francis *et al*. (2016) documented parasitoids; *Encarsia guadeloupae, Encarsia noyesi, Aleuroctonus* spp.; predators *Nephaspis oculata, Azya orbigera, Chilocorus cacti, Cryptolaemus montrouzieri, Delphastus pallidus, Harmonia axyridis, Hyperaspis bigeminata, Cybocephalus* sp. and *chrysopid, Ceraeochrysa* spp. in Florida associated with RSW. In various States of India, *E. guadeloupae, E. dispersa*, *E. noyesi, Alueroctonus vittatus* and *Nephaspis oculata*, *Mallada* spp. and *Cybocephalus* spp. enlisted as natural enemies of RSW (Selvaraj *et al.*, 2016; Rao *et al*., 2018). In addition, a predator *Pseudomallada astur* (Neuroptera: Chrysopidae) and the entomopathogenic fungus, *Isaria fumosorosea* Wize (Hypocreales: Clavicipitaceae) play a major role in reducing the population of these invasives (Sundararaj, 2021). *E. guadeloupae* is found to parasitize RSW in Sri Lanka (Aratchige *et al*., 2023).

In Florida, *E. noyesi* is giving good control of RSW (Taravati, *pers.comm*.) Among the two parasitoids, found in India *E. guadeloupae* was more predominant and reported to cause higher parasitism of up to 80% on RSW varying across different States and different periods of the year. Parasitism by *E. guadeloupae* which was initially found to be 10% - 15% has rose to as high as 70% - 80% in a period of five to eight months in Tamil Nadu and Kerala (Mohan, *et al.*; 2017, Rajkumar *et al.,* 2020). Parasitism has ranged from 31.6% - 57.6% in a shorter period from August to December 2018 (Kolanthasamy and Nelson, 2020).

Two entomopathogenic fungi viz., *Isaria fumosorosea* and *Simplicillium lanosoniveum* were found associated with RSW and were used in the bio-suppression of the pest in India (Sundararaj *et al*., 2021). Besides these parasitoids, other commonly found predators are playing complementary roles in reducing RSW populations.

No parasitoids of BNW have been reported yet. However, several predators feed on them in the coconut fields in India (Sadhana *et al*., 2023).

Hispid beetle

The coconut hispid beetle is native to Indonesia and Papua New Guinea, where it seldom causes serious problems. From 1929, it has spread to Pacific islands, Asia and Australasia and attacking not only coconut palm but also cultivated and wild palms. Later, it was reported in Singapore, Vietnam, Nauru, Cambodia, Laos, Thailand, Maldives, Myanmar and Hainan Island (China) (CABI; Waterhouse, 1985; Singh and Rethinam, 2004). In the absence of natural enemies, it has become a devastating pest in the countries invaded by the beetle.

Both adults and larvae damage the leaflets of young unopened fronds. They feed on leaf surface and feeding scars enlarge to form irregular, brown blotches as the frond opens. The brown areas shrivel and curl, giving the leaf a characteristic scorched, ragged appearance. Large areas of the leaflets break off leaving the foliage partially skeletonized. As the leaflets separate when the fronds expand, the adults move to attack younger leaves. Destruction of young leaf tissues restricts growth for a long time and heavy attack may cause death of palms, especially seedlings.

Chemical control with several insecticides has been used to control the coconut leaf beetle. Some insecticides are also injected into the trunk of infested palms. However, the effect of these treatments lasts only for 3 - 4 months. Repeated applications are impractical and uneconomic and cannot be used as a long-term control measure.

Due to unsustainability of chemical control, management of hispid beetle is mainly focussed on biological control. Several species of natural enemies, particularly, parasitoids have been recorded (see review of Rethinam and Singh, 2007). The most introduced and distributed parasitoids of *B. longissima* are the larval parasitoid, *Asecodes hispinarum* Bouček and pupal parasititoid, *Tetrastichus brontispae* Ferrière. The history of biological control of this pest in Indonesia and the Pacific from 1932 to 1984 is reviewed by Waterhouse and Norris (1987).

The introduced parasitoids have been successful in establishment and suppression of *B. longisimma* in respective countries. Few examples of successes are described. *A. hispinarum* and *T. brontispae* were introduced into China in 2004 and have approved to be very functional. The parasitisation was 90% - 100%. Field recoveries were made in some regions after parasitoids were released however, the parasitisation is not always so high. It is necessary to release substantial numbers of the parasite into suitable populations of *B. longissima* to ensure establishment. Environment and climate might affect

the survival and effectiveness of the parasitoid (Lu and Peng, 2017). Up to 50% parasitism of Hispine beetle by *T. brontispae* has been observed in different islands in Indonesia (Hosang *et al*., 2004). A steady decline in damage was recorded in Western Samoa from 42.4% in 1984 to 15.4% in 1987, following the release of *T. brontispae* and Asecodes sp. [possibly *A. hispinarum*] during 1981-1986 (Vögele and Zeddies, 1990).

Brontispa can be controlled on young palms by spraying suspensions of entomogenous fungus, *Metarhizium anisopliae*. The fungus is capable of spreading rapidly during wet weather, killing more than half of the *Brontispa* larvae and adults present (Waterhouse and Norris, 1987). Use of *M. anisopliae* for the management of the pest has also given positive results in Indonesia (Hosang *et al.,* 2004; Singh and Rethinam, 2004).

Oryctes beetle

O. rhinoceros is endemic to the coconut-growing regions of South and South-East Asia from Pakistan to the Philippines (CIE, 1967). Its current distribution is given in CABI compendium.

Adults feed in the crown region of coconut by boring through petiole bases into the central unopened leaves. This causes tissue damage and attacks subsequently produce fronds which have wedge-shaped gaps or the characteristic V-shaped cuts. In some instances, the bud leaf break and seen hanging on the crown. The damage to young palms and seedlings affects their growth. Severe damage to seedlings could result in malformed seedlings and even death.

Several control methods are available for *Oryctes* beetle and use them integrally gives successful results.

Cultural control - The adult beetle is free living, but the larvae and pupae spend the development period on decaying vegetable matter. Sanitation within and surrounding the plantations, especially destruction of the potential or existing breeding sites of this pest, provides an important basis for its control. Manure heaps and pits may have to be covered or alternatively turned regularly for the removal of the grubs (Catley, 1969). Hence, estate sanitation by destruction of such breeding grounds is important in their management.

Mechanical control - Removal of the adults from the point of attack in young palms by using a hooked piece of wire is a common mechanical control technique to reduce the number of adults in an infested area. This practice is often costly, labour intensive and needs to be conducted regularly, provided that sufficient labour is available.

Chemical control - Most of the chemicals applied are targeted to control the adult stages attacking the spear of the palm. The point of application is therefore at the base of the leaf sheath. Insect-repellent naphthalene applied (as moth balls) fortnightly to the frond axils provided 95% control of the pest (Singh, 1987). Application of used engine oil or coal tar acts as a repellent to beetles. Several insecticides are effective in controlling the attacks short term, but due the environmental hazards, difficulty of application and harmfulness to humans/animals they are not widely recommended.

Pheromonal control - A male-produced aggregation pheromone, ethyl 4-methyloctanoate (E4-MO) was discovered (Hallett *et al.,* 1995). It has been synthesised and is available commercially. The pheromone is stored in a small, heat-sealed, polymer membrane bag or glass capillary and placed in traps. The beetles attracted by the pheromone are trapped inside the trap. It is very useful as a monitoring tool, and as an economical control method. Different trap types were developed to use the pheromone; the vane trap using two metal cross vanes mounted in a bucket (Bedford, 2014) and plastic pipe of 2 m long and 15 cm diameter with 2 windows for the beetles to enter are commonly used. These traps when placed at one trap per 2 ha. effectively trap many beetles, both males and females.

Biological control - Biological control effort concentrated on *Oryctes rhinoceros nudivirus* (OrNV) after its discovery in Malaysia in 1965 and its successful introduction into Western Samoa in 1967 (Waterhouse and Norris, 1987). OrNV and the pathogenic fungus *Metarhizium anisopliae* have been utilized further for field control of this pest in several countries (George and Kurian, 1971; Bedford, 1986). For OrNV, the adult beetles are dipped in a suspension of ground, infected grubs. They are then allowed to crawl about for 24 hours through sterilized sawdust mixed with the above suspension. They are then released back into the plantation to infect other adults and larvae in the breeding sites (Bedford, 1976). OrNV suspension may also be applied directly to the mouthparts of adults to infect them for release. The fungus *Metarhizium anisopliae* var. *major* may be produced commercially or in bulk by various methods, for release by suitable means into breeding sites (Tey and Ho, 1995).

PROPOSED IMMEDIATE INTERVENTIONS FOR THE MANAGEMENT OF RSW IN MALDIVES

Immediate follow up actions are required for management of RSW and its spread. The following immediate follow up actions are recommended for the management of whitefly infestation.

1. Spray neem oil and soap solution to at least young palms having initial signs of re-infestation. This is especially required in L. Fonadhoo (young palms along the roadside), L. Maandhoo

(young palms opposite Fisheries complex), ADh. Maamigili, Gn. Fuvahmulah City, S. Addu City (Hithadhoo) and S. Addu City (Hulhumeedhoo). It may be required to repeat spraying in 6 weeks later if pest persists.

[Dissolve 10 ml of neem oil, 5 g. of soap powder in one liter of water to prepare the solution. Spray the leaves, especially the lower ones thoroughly with about 3 - 4 liters of solution. Spraying should be carried out in the evenings as neem oil is photosensitive. Do not spray on rainy days]

2. Prohibit transportation of coconut leaves or any other infested plant parts from islands with whitefly infestation to un-infested islands.
3. The most effective and sustainable solution for managing whitefly infestations is use of natural enemies, particularly parasitoids and predators. Presence of parasitism in many localities is a positive sign in this direction. Although, parasitoids can multiply and spread by itself, their action could be enhanced by augmentative releases. It is possible to collect parasitoids from the field and commence a mass rearing programme. These lab -bred parasitoids could be released in areas where parasitoids are absent or in low numbers. Hence, it is strongly recommended to commence a biological control programme for the management of whiteflies in Maldives. The first step would be to rear whiteflies in caged conditions in net cages. It is recommended that the Ministry identifies a suitable island and an officer to carry out this activity. HDh. Hanimaadhoo Agricultural Center could be a suitable choice. Methodology of rearing whiteflies was made available. Training of officers on mass rearing was given to the officers at the Consultants second visit to Hanimaadhoo.

ASSESSMENT OF THE COCONUT SUPPLY AND VALUE CHAINS

Supply and value chain specialist made assessment of the coconut industry by visits to the coconut cultivations and processing facilities in different islands. In addition, the specialist visited retail shops and wholesale market in Male for the assessment. It was noticed that there are extremely limited coconut industries currently operating in the Maldives. They too are carried out in a small scale. In general, it was observed that Maldives coconut sector has no organized coconut supply and value chains. Value addition of coconut is barely done and there are no large-scale industries for processing of coconut.

Wholesale coconut and value-added product market in Male

Supply chain

The manufacturer, the supplier, the transporters, the warehouse, the retailers, and the customers are all part of the supply chain. It was noted that supply chain of coconut in Maldives are multi-layered and intricate, extending from the location of production to long distance markets. Technical and business skills of the farmers needed to run the coconut plantation and sharing information of supply chain with the people further down the chain are lacking.

Discussions with the stakeholders revealed that in the past Maldivian coconut sector has contributed immensely to its economy and surplus coconut had been exported as copra. However, due to subsequent development of the tourism sector, fisheries industries, and other agricultural sectors along with high demand for land for housing, expansion of infrastructure and other industries, limited opportunity for expansion of land area, coconut has become a low priority crop. Currently, the coconuts produced in the country are mainly consumed as fresh nuts in cooking, tender nuts in making sweets and young tender coconut (*Kurumba*) as a beverage. Young coconut has a high demand within the islands as well as in tourist resorts. Toddy tapping is being carried out in limited scale in some islands.

Toddy tapping at Fuvahmulah Island

Value chain

The coconut value chain is extremely complex due to the many products that can be derived from its roots, trunk, leaves, kernel, husk, shell, and water. The coconut value chain is connected in the Maldives' islands and forms a key part of almost all farming systems in all islands. Coconuts are overwhelmingly a smallholder crop and households use income from coconuts to finance their basic needs and very little is re-invested in the cultivation, or in value-adding through by-product utilization or diversification into higher-value products. In addition to consumption, some rural households use coconut trunks to produce building material and dried coconut leaves to weave roofing sheets to generate income. Value addition to coconut is done at a very small and basic level. Copra is the most popular value-added product that brings income to rural households, especially in the more remote areas.

The specialists visited one of the coconut rafter mills, toddy tapping estates, coconut sugar manufacturing household, Cadjan weaving sites, masala production household, ekel broom, coir rope manufacturing sites. Also, it was observed that mature coconuts are processed into virgin oil by a small-scale manufacturer in Meedhoo and add value by producing scented soap to be sold to tourist resorts. This entrepreneur has imported the required machinery from overseas and carries out production hygienically.

Coir peat processing unit – Hanimaadhoo Island

Virgin Coconut oil project Meedhoo Island

Cadjan weaving at Kaashidhoo Island

GAPS IN SUPPLY CHAIN AND VALUE CHAIN

Several gaps in supply and value chain were observed. Out of them primarily obstacle is insufficient supply of nuts to the industry. Low nut production has also resulted in importation of coconut, vegetable oil and coconut milk powder to the country, which in turn has effects on the industrial development. Table 4 explains the status and gaps of supply and value chain of the coconut industry in Maldives.

Insufficient supply of coconuts

The supply and value chain of the Maldives coconut industry depends on the availability of nuts and the volume of other plant parts such as shell, timber, husks and leaves to operate the industry. The nuts that are produced in the country are mainly used for consumption and the balance is utilized in industries. It was observed that currently, the availability of nuts for the industries is low due to low production, wastage, and losses due to biotic and abiotic factors.

Poor or no management of coconut cultivations, as discussed previously has led to low coconut production. In addition, no proper harvesting programme of nuts seriously affects the coconut supply. In Maldives, nuts are not picked. Hence, mature nuts fall and germinate on the ground, if not collected. In several islands undergrowth of coconut seedlings of various ages was a common site. In addition to waste of nuts in this way, the dense undergrowth has created a situation that collection of fallen nuts impossible adding further to the nut wastage.

Table 4. Current Status, gaps in supply and value chain and contributory factors of coconut industry in Maldives

	Status, gaps and issues	**Contributing factors**
Supply chain		
Coconut production and farmer interest	• Low coconut production • Neglected coconut lands • Low farmer interest	• Neglected coconut cultivation belonging to the island councils and government • No coconut picking program • Lack of skilled labour • High density plantations • Other interfering trees in coconut cultivations • Lack of quality seedlings • Presence of senile palms • Lack of coconut-based farming systems • Poor technology transfer program for value addition and culling unproductive palms • Pest and disease outbreaks • Limited land availability • Absentee land ownership. • Competition for land from tourism, high value fruits and vegetables and other commercial use
Value Chain		
Value chain gaps	• Availability of coconut for this industry • Lack of knowledge on value addition	• Low or no surplus nuts for processing • Low productivity • High demand for young coconut • Lack of technical know-how and certification • Small size of operation • Scattered small islands • Availability of transport facility, distance, and high cost of shipping
Marketing	• Buying imported coconut oil and milk, low demand for local customers • Poor marketing network	• Competition from vegetable oils and coconut milk. • Lack of knowledge and health benefits for coconut products. • Unorganized small holders. Corporative for bulk trading is not available. • Small land area, remoteness of the islands, high cost of shipping • Lack of market information and limited market promotion • Lack of institutional support.

Logistics

In the Maldives geography and logistics have always been the biggest challenge for the investors, project funders and to the project managers. Apart from geography, another major challenge is a lack of organized transportation network within the country. Since, resorts are built in isolated islands the developers and the managers handle all logistics. As a result of private transportation, the prices of goods further increase without any control.

Farmers transport coconut and agricultural produce to Male and other islands mainly by boats locally known as "*Dhoni*." These boats do not have proper storage compartments, unlike cargo ships. If goods are not properly packed, protected with waterproof packaging, especially fertilizers, the standards may drop from being directly exposed to saltwater while being transported. Apart from the distance, finding safe harbours for vessels ferrying goods is also an issue. Since some islands do not have a harbour, loading and unloading of goods is highly challenging, depending correct timing of the tide. If the supply boat reaches the island during low tide, they have to wait several hours until tide rises before, they could unload the goods.

Industry potential

There is an enormous potential for promoting value added coconut-based products in Maldives Coconut growers and manufacturers are willing to add value to coconut while small-scale manufacturers wish to increase their capacities. The government and island councils are willing to assist the upcoming industrialists. The market for coconut-based products is two prone. Local market, especially targeting tourism industry and overseas market. Coconut products have a high demand worldwide due to its health benefits. Further, presently, people are moving for consumption of healthy natural products. In this scenario Maldives can easily cater to their own tourism industry by increasing supply of tender nuts of different colour forms, which may attract tourists and by producing and supplying coconut ice cream as a healthy thirst quencher. These have a demand among locals too. Virgin coconut oil and its value-added products such as scented soap, skin care products, therapy massage oils, body lotions and hair and skin conditioners can have a niche market in tourist resorts. If adequate intensive awareness on the health benefits of coconut oil and products is made among the Maldivians, coconut products can infiltrate the local market preventing import of vegetable oils and foreign exchange. Coconut oil and its by products, coconut flour (by product of virgin coconut oil processing) and copra meal could be used in bakery products and animal husbandry, respectively. In addition, coconut timber, coir, coir peat (by product of coir production), shell products such as charcoal and ornamentals could be produced in large scale as well as cottage industries.

Developing effective value chains to connect farmers to markets and boost value-adding activities through improved technology and inputs, processing, export from islands to Male and resorts, and advanced infrastructure would help boom the coconut industry in Maldives.

Importance of adding value to coconut and by-products to enhance revenue

Coconut products and by-products can be commercially utilized for multiple purposes. It is also a source of fiber, timber, and fuel. The coconut palm is also a beverage crop in many islands in the Maldives. The dried kernel or the copra is the richest source of cooking oil, which is also used as hair oil, body oil, and industrial oil throughout the country. It is an illuminant and lubricant as well. Coconut oil is an ingredient in most premium cosmetic products. Coconut oil yields many oleo chemicals which have wide applications in various sectors. It can also be converted into biodiesel. The coconut oil cake, the residue obtained after the extraction of oil from copra is a good cattle feed. Coconut palm yields toddy from which jaggery, vinegar, and arrack are manufactured. The timber of coconut is used in house construction and to manufacturing furniture, wall panels, show pieces, and floor tiles. The tender coconut is used as a nutritious health and sports drink and the water of mature nuts can be used to produce vinegar, jelly, Nata de coco, and wine.

The shell is used as a fuel besides manufacturing various commercial products such as shell powder, shell charcoal, and shell-based activated carbon. The soft bud of the palm is edible and nutritious. Spongy ball-like haustorium developing inside the nut when stored over a period is a sweet delicacy that can be exploited as a commercial value-added product. The leaves of the palm are used for thatching houses and restaurants and for fences. The midribs of leaves are used to make brooms, fish traps, baskets, and toothpicks. The husk yields fiber and pith. The fiber is made into hundreds of products, which enjoy both domestic and export markets. The pith is a soil conditioner and rooting medium besides having many other uses. The spathe and stipules are used as fuel and for manufacturing handicrafts.

There is a considerable amount of foreign exchange spent by the Maldives government to import coconut and value-added products. Therefore, it is beneficial to improve the productivity of existing coconut cultivation and add value to coconut to get high-quality products for consumption, supply to resorts and exported to niche markets. Table 5 indicates that Maldives imports coconut milk copra oil, desiccated coconut, palm oil, and coir peat in which the highest foreign exchange is spent for importing coconut milk. The total value of imports of coconut and coconut-related products from 2020 to 2022 was MVR 159 million including palm oil according to the available data from Maldives Customs Service, 2023. These figures indicate that there is huge potential for adding value to coconut and by products in the means of import substitutions.

Table 5. Imports of Coconut and Coconut Products from 2020-2022

Products	2020		2021		2022		Total Quantity for years 2020,2021, 2022	Total Value for years 2020,2021,2022
	Quantity (KGM)	Value (MVR)	Quantity (KGM)	Value (MVR)	Quantity (KGM)	Value (MVR)		
Desiccated Coconut	55,574	374,497	81,001	5,225,373	150,823	7,781,835	287,398	13,381,706
Coconut Excluding Desiccated	1,167	91,699	5,988	534,035	2,869	201,598	10,023	827,331
Coconut Milk	970,478	27,724,992	77,102	35,604,789	98,163	48,825,143	1,145,743	112,154,924
Coconut (Copra) oil			32,377	1,867,711	36,474	2,845,978	68,851	4,713,689
Palm oil			172,382	3,445,277	800,733	17,002,711	973,115	20,447,988
Coir Dust	934,124	3,260,418					934,124	3,260,418
Coir Husk, coir dust & Coco peat	4	155	484,732	2,289,374	532,603	2,098,458	1,017,339	4,387,987
		31,451,761		48,966,559		78,755,722		159,174,042

Source: Maldives Custom service

RECOMMENDATION OF POSSIBLE TECHNOLOGICAL INTERVENTIONS TO REVITALIZE THE COCONUT INDUSTRY IN MALDIVES AND A STRATEGIC PLAN FOR IMPLEMENTATION

In the Maldives, the coconut sector must compete with tourism sector and fruits and vegetable sectors that are able to make more profitable use of the land in many islands. Thus, the coconut sector faces greater difficulty in attracting and retaining investment, and in justifying the use of resources for maintaining the existing coconut lands. Given the increasing competition for land, it has become essential to increase the productivity and profitability of existing land. However, increasing productivity is not a straightforward exercise as coconut cultivation in Maldives is scattered in many islands in a wide range of agro-ecological zones on lands with different cultivated areas while the availability of inputs and technology differ among islands. Therefore, given the competition from alternative land uses, the most suitable approach would be to manage existing coconut cultivation to increase yield and improve land productivity, harvest available coconut to increase the nut supply, reduce crop losses due to pests and introduce technology to add value to stimulate the development of the coconut industry and improve profitability.

Further, effective harmonization of all sectors related to coconut is utmost important to revitalize the coconut industry in the Maldives. Implementation of sound agronomic interventions will increase the coconut production and productivity of coconut lands, which in turn enhance the effectiveness of the coconut value chain. Also, a well-designed pest management programme will reduce crop losses due to various pest damages and thereby adding a greater number of nuts to the coconut supply chain. Eventually, an efficient coconut supply and value chain management and value-added products would revitalize the coconut industry in the Maldives bringing large income to the country. The schematic chart (Fig. 15) shows the interconnection of different factors identified for revitalizing the coconut industry in the Maldives.

However, several gaps in current coconut production, pest management and supply and value chains exist as described in previous sections. Proposals with detailed descriptions for addressing these issues are given in this section. Further, a strategic plan giving possible short-, medium- and long-term technological interventions to improve coconut production and productivity, manage pests of coconut and possible future biotic threats and techniques in adding value and improve the coconut value chain is presented.

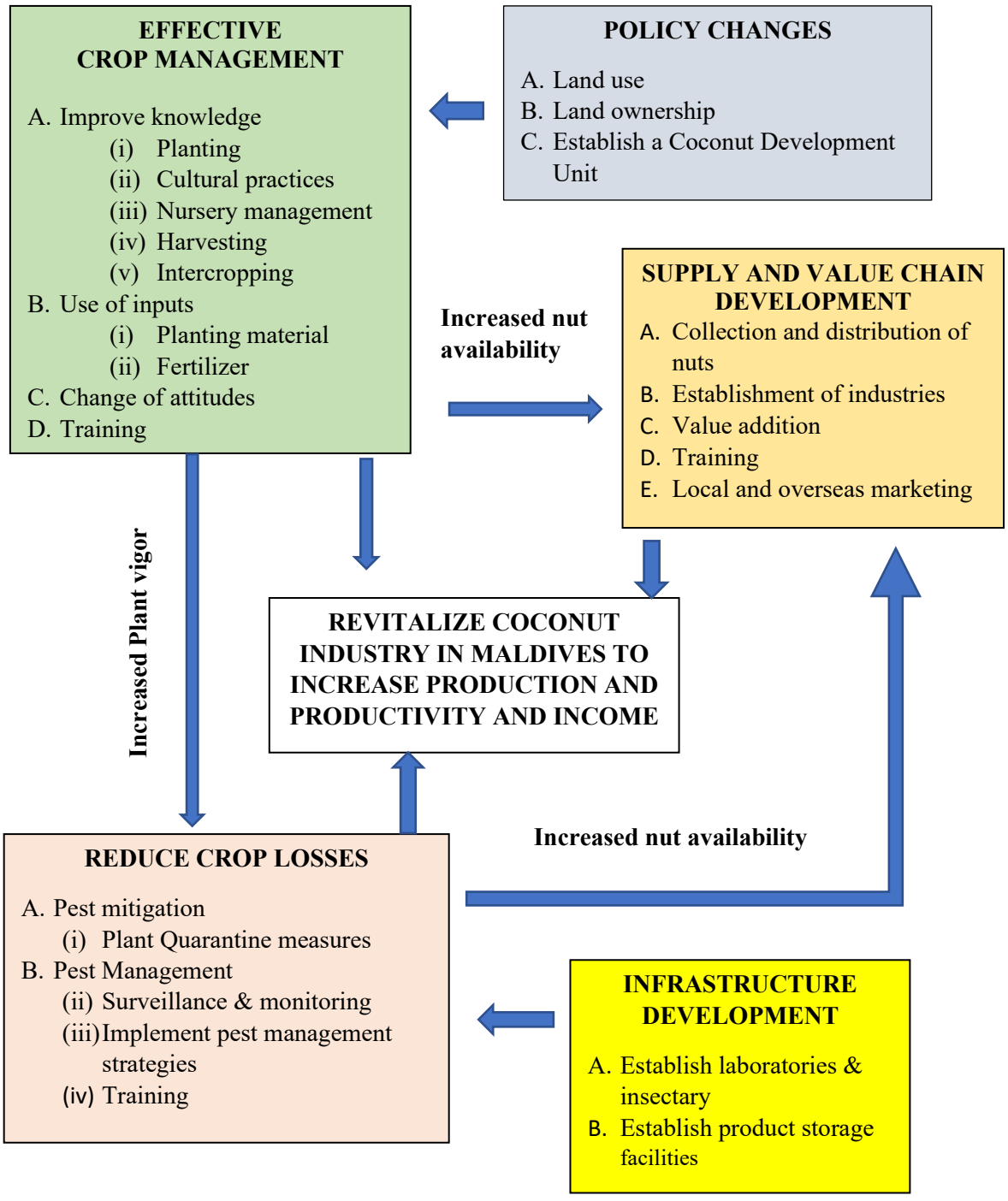


Figure 15. Schematic diagram showing the interconnection of different aspects for revitalization of coconut industry in the Maldives

PROPOSED AGRONOMIC INTERVENTIONS FOR REHABILITATION OF COCONUT PLANTATIONS / HOLDINGS TO INCREASE PRODUCTION AND PRODUCTIVITY

1. Understanding the fundamentals of coconut palm

It is vital to understand the fundamental aspects of morphology, biology, and physiology of the coconut palm to adopt suitable technologies in a scientific manner. This is described in Annex 2.

2. Prior requirements for rehabilitation of coconut holdings

2.1 Reducing plant density in overcrowded coconut holdings

In the process of coconut sector rehabilitation, the implementation of activities should be planned based on the prevailing conditions in small-, medium- and large-scale neglected plantations. In some situations, the existing population of palms could be rehabilitated within 2 – 3 years by changing the internal environment and improving the health of individual palms. The change of internal environment refers to activities such as cleaning the undergrowth in palms avenues, removal of excess palms to bring down the palm density to an acceptable level and implement required agronomic practices to improve palm health and overall land productivity. But in some situations, the physical condition of existing palms is so weak that they could not be rehabilitated within a reasonable time. Under such situations, it is advisable to remove all the palms and establish a new cultivation in the same block with improved coconut seedlings as per the details given under the category of replantation (see Annex 3). With proper after care and seedling management, the seedlings of the replantation system will come into bearing early. Tall coconut types will take about 4 – 5 years, whereas dwarf and hybrid varieties come into bearing within 3 – 4 years.

Depending on the market demand and the availability of planting material growers could decide which type of planting materials should be used. For higher nut production, new coconut hybrids could also be used for these planting programs. Planting distance and densities are different based on their size of canopies.

In large, neglected coconut plantations over 80 to 90% percent of palms are very weak and senile, so that the rehabilitation approaches should be different. As these plantations have been originally planted with mostly in correct densities and distance, a rehabilitating system referred as “underplanting” could be carried out (see Annex 3). The underplanting system could only be recommended for coconut plantations where old plantation had been planted in rows with correct distance and densities. In this underplanting system, new coconut seedlings are planted right in the center of square of old palms in a

way that all seedlings are positioned on the line in the center of old coconut rows. However, after the complete clearing of undergrowth all very weak, unproductive, and diseased palms should be removed as the first step to reduce the density of the old stand. At the initial stage, the palm density reduction should be around 30% of the old stand.

In certain situations, neglected high density young plantations are found in a fairly large extent. Different rehabilitation approaches should be followed in this case. Removal of excess young palms must be carried out based on the productive and health status of them. Firstly, mark all healthy and potential palms within the existing population considering the distance to each other and the density per acre/hectare. Secondly, rest of the palms should be removed to maintain the palm density. Then the recommended management practices must be carried out to improve the nut production levels.

Removal of excess palms

Systematic removal of palms must be carried out to bring down the palm density to an acceptable level. The most suitable density of palms required for profitable cultivation is found to be 158 per/ha or 64 per/ac with the spacing of 8 m x 8 m or 26 feet x 26 feet. However, it is not an easy task to bring down the palm density as above by removing excess number of palms. Under such conditions, it can be acceptable to maintain little higher densities than the norm. As an alternative method, in high density mature cultivations, palms found closer than 22 feet or 6.7 meters should be removed. Once the density of palms is brought down, palm rehabilitation activities with the recommended management practices could be carried out.

Excess palms

Clearing of undergrowth before rehabilitation in Maandhoo

2.2. Clearing of thick undergrowth within coconut avenues

Before implementing the rehabilitation package, the ground condition of all neglected plantations/ holdings needs complete clearing by uprooting all vegetation found within coconut avenues. In large plantations, heavy machinery could be used to uproot and vegetation including naturally grown coconut seedlings. In the case of small and medium scale neglected holdings, it is also essential to clear the entire ground area, as the first step of rehabilitating activities. Complete clearing of the ground condition, is essential to minimize the root competition for nutrients and water, enable the collection of fallen nuts and facilitate the execution of required rehabilitation practices. Disposal of the uprooted vegetation will be a challenging task that has to be carried out in consultation with environmental authorities in the island. In this case, certain options may be proposed for consideration.

a. Heap them in the center of the coconut square and burnt them little by little, when dried.
b. Transport them to a bare land and allow to decompose in heaps.
c. Crush all vegetative materials with a heavy duty crushing or chopping machine and use them for composting.
d. Bury them in pits cut in different areas within the plantation.

2.3 Conducting palm census

The next step of the rehabilitation activities is conducting a palm to palm censes of the existing plantation/ holding. The palm census is essential for large plantations to assess the situation of palms and facilitate the cost estimation for rehabilitation project. Before conducting the palm censes, the entire land area must be surveyed to measure the exact extent of the land. Physical counting of palms under the following categories should be carried out by officers who are trained for this purpose.

Categories of palm census to be recorded in neglected plantations.

1. Number of palms that can be rehabilitated
2. Number of very old palms that should be removed/ replaced
3. Number of very weak palms that are to be removed/ replaced
4. Number of dead palms to be replaced
5. Number of palm vacancies that are to be filled

3. Rehabilitation package for coconut

A rehabilitation package is given describing the agronomic practices required for successful plant growth and nut production, mother palm and seed nut selection and raising high quality seedlings for national planting requirement and intercropping under coconut for higher land productivity (Annex 3).

Coconut Research Institute Advisory Circulars could be downloaded from www.cri.gov.lk for further details of different practices.

The rehabilitation package includes the required agronomic practices for the first category of palms to increase their nut production and land productivity. Other essential technical advice required for replacing palms in vacant places and managing them to fulfil the objectives of the plantation rehabilitation package have been described below.

4. Implementation of the rehabilitation programme

The coconut sector rehabilitation program cannot be considered as an isolated activity bringing about expected changes in the present cultivation system. The rehabilitation involves the introduction of new ideas and methods into the present system in order to increase the nut production and overall productivity of the sector. This requires a total transformation of the type of technology and associated social setup of the sector. Sector rehabilitation is a process which runs over a period of time and not a single onetime activity. For the success of the rehabilitation process, the implementing organizations must consider the main element as knowledge and skills, technical advice and information, farmer organization and motivation, and developing self-confidence. To fulfil these requirements, a strong extension setup is essential to disseminates technology, enhance farmers knowledge, provision of materials, changing the attitudes and monitoring and impact evaluation (Oakley and Garforth).

4.1 Reforming the existing extension organizational structure

In Maldives, the agriculture related development objectives are outlined in the National Development Plan. Under the agricultural policy of this plan, the Ministry of Fisheries, Marine Resources and Agriculture has the overall mandate for the sustainable management and development of the national fisheries, agriculture and marine resources. The policy also covers the development of the infrastructure and provide institutional support to maximize economic and social benefits. Primary production methods of agriculture in the Maldives, at present fall under two categories; Home based farming which is mainly for own consumption and crop cultivation at semi-commercial level and crop production at commercial level in uninhabited islands leased for long term development.

Under the present agricultural policy, the coconut sector development has not been given adequate priority even in the highest level of policy making. Since the rehabilitation of the coconut sector is now identified as a major agricultural intervention, the present policy must be reorganized to achieve the expected goals and objectives. For the successful implementation of the coconut sector rehabilitation, the current extension organizational and functional activities are to be reorganized with the

establishment of a new "Coconut Development Unit" under the ministry. The proposed structure for the Unit is given below.

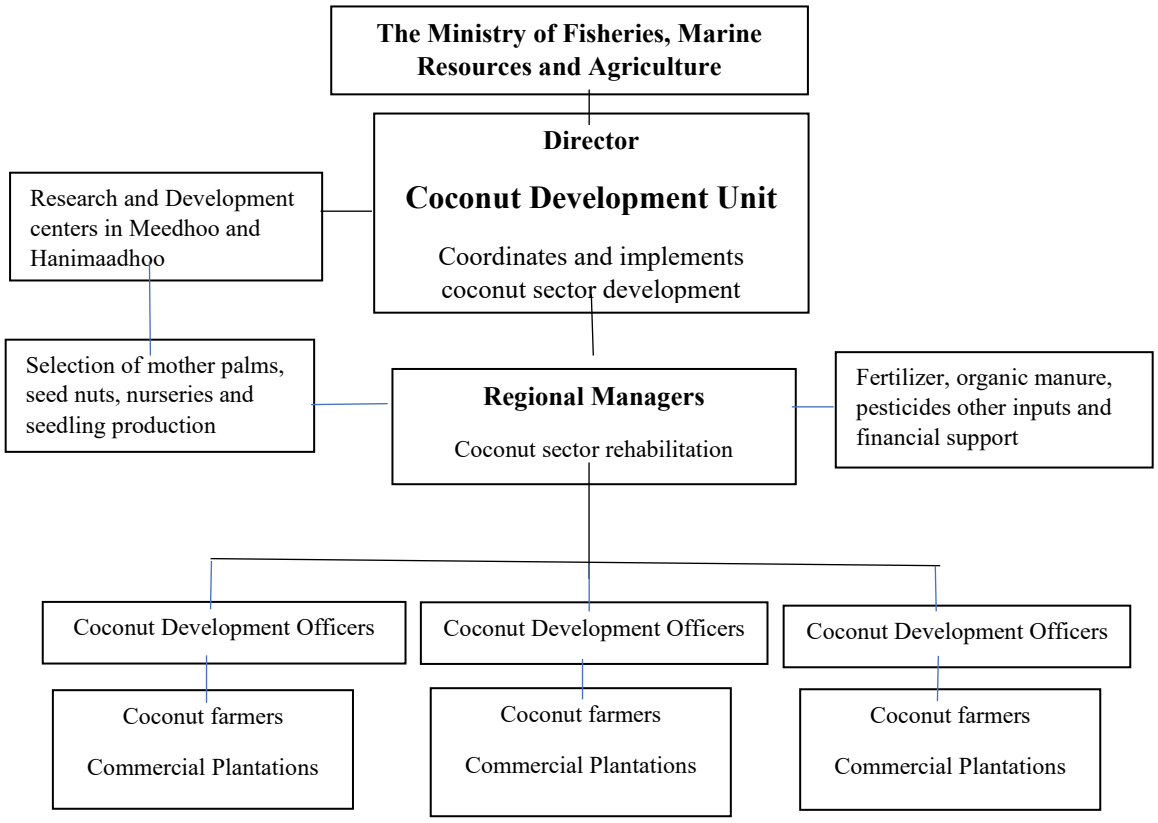


Figure 16. Proposed organizational structure for the new Coconut Development Unit

Under the new organizational structure, clear functional activities are to be identified based on the locational needs and priorities to fulfil the overall development objectives.

Ministry in Male coordinates all administrative and implementation functions of the Unit. The production of coconut seed nuts, seedlings and their distribution in different nurseries are to be coordinated by the Coconut Development Unit (CDU). One of the key functions of this unit should be technology dissemination to end users, training, advisory services, farmer participatory field demonstrations, farmer organizations, and assessing the overall impact at the field level. The provision of inputs like fertilizer, organic manure, agrochemicals and pesticides is also a responsibility of the Unit.

The Meedhoo Agricultural Centre, located in the Central Southern Development Region and the Hanimaadhoo Agricultural Centre, located in the Northern Development Region could conduct research and generate technologies. Technologies related to the production of coconut hybrids and selection of

mother palms, collection of seed nuts and production process of high-quality planting materials are also be mandated to these centers.

To coordinate and implement the coconut sector rehabilitation activities within each island, young, educated officers must also be appointed as Coconut Development Officers (CDO) under the responsibility of the Regional Managers. The CDO responsibility is to work with farmers, commercial plantations, and administrators to provide necessary technical knowhow and supplies for the successful implementation of the proposed rehabilitation packages. The whole development process is dependent upon the efficiency and dedication of the officers appointed. CDO as an extension agent must be responsible for providing the knowledge and information that will enable farmers to understand and decide about the required technologies and communicating the knowledge to coconut growers. After the appointment of suitable officers, they must be given a through training to enhance their technical knowledge and personal skills on organizing and planning, communication, analysis and diagnosis, leadership, and initiative (Robert Chambers, 1990).

For effective implementation of the rehabilitation activities as planned, they need to have full access to required technologies for their own use and for training of farmers and other supportive officers. However, at present, the use of basic coconut cultivation and management technologies at the farmer level is highly unsatisfactorily because there is no technology dissemination, training, advisory and farmer support services available at the grassroot level. Farmers and officials are highly lacking in technical understanding about the basic biological and agronomic requirements of coconut palms.

Considering issues, limitations, and problems in the coconut rehabilitation program, it has now become essential to formulate a full-scale "Coconut Technology Manual*"* with scientific explanations. The proposed manual should be prepared in such a way that illustrations used as a field manual guide comprising all necessary information required for training and educational programs. The necessary guidelines on the program budgeting, planning, implementation, monitory and evaluation also be included. All the technical aspects covering the sector rehabilitation program must be included in a simple way that everybody can understand and practice. The manual must be translated to the local language and printed in attractive colour format must be available to officers, farmers, and stakeholders. Based on the needs of the rehabilitation interventions in the coconut sector, extension and training activities are to be planned and implemented with the best participation of stakeholders. Several extension strategies could be used to achieve the expected results at the farmer's level.

4.2 Strengthening extension strategies

Training programs - Training programs are conducted both in research and extension centers and in farming communities. Such training programs consist of theoretical and practical sessions. During the trainings with farming communities, the extension staff conduct field visits to familiarize with problems and constraints.

Farmer Field Schools - Farmer Field School is a group-based learning process, enable farmers to understand their problems, limitations, and suitable corrective measures with a mutual agreement of the famers in the same localities. Extension staff acts as a facilitator while farmers are given the opportunity to practice their conventional methods and recommended methods in one particular plot at the same time. This method of farmer education is found to be effective as farmers learn through with their own initiative.

Agricultural fairs – Fairs are more suitable to conduct in city islands, which are surrounded by small islands. New cultivation and management technologies could be demonstrated in these fairs. Agricultural fairs are suitable platforms to disseminates new information to create interest among the participants.

Field Visits- Extension staff should carry out field visits during the trainings in farming islands. It is important to accompanied by participants in some of the visits to make them observe the fields and identify related problems and shortcomings.

Office calls- Arrange farmers visit to research and extension centers from time to time to familiarize with innovations and new extension interventions. Centers normally maintain field demonstrations to show the benefits of good management practices. Extension and research officers help them identify the disorders when affected samples are brought to the center.

Extension with Mass media – This method ensures a wide coverage with a low cost per unit. Live and recorded TV and Radio programs could be used effectively to create the awareness and interest among the public on the target activities.

Social media platforms – Fastly developing social media platforms and online activities could be used effectively to create awareness and interest among the public. Stakeholder groups, online meetings and discussions for technology dissemination process.

4.3 Changing land policies

In coconut growing islands, owing to land scarcity, the full authority of lands comes under the responsibility of respective councils. Block of lands are issued to residents for housing and farming for a short period, which is extended by the council. Other lands with coconut holdings are mostly managed by the council. However, majority of these holdings are severely neglected for many years without making a reasonable revenue. In a particular day, residents in the area are allowed to collect fallen coconut from city council owned holdings for their own consumption. In this condition, either residents or the council have no interest to rehabilitate these coconut holdings. In some other islands, blocks of fertile lands are issued to people for the cultivation of vegetables and fruits for a short leasing period. Although they are interested to cultivate coconut along with vegetable and fruit trees, the short land leasing period prevents them from planting high yielding coconut as it requires more than five years to provide a reasonable income. It was observed that at presently, in many islands, large extent of coconut lands has been neglected for many years without making the best use of fertile soil and other resources. Now it has become essential to have an integrated coconut rehabilitation program, for each island, with proper scientific guidelines and cost-benefit analysis.

POSSIBLE SHORT, MEDIUM, AND LONG- TERM MEASURES TO MANAGE CURRENT PESTS AND FUTURE BIOTIC THREATS

Either indigenous or exotic, possibility of eradicating a pest once established in a country is very remote. Therefore, pest management aims at keeping pest numbers below a level that its population does not cause an economic damage. Generally, success of pest management is achieved by combining more than one management strategy (Integrated Pest Management) while risk mitigation is important for preventing entry of alien pest species and even spread of pests within a country. The following recommendations are made for an effective pest management programme on coconut and mitigate risk of new pest/ disease invasions.

1. Strengthening plant quarantine measures.
2. Implementing surveillance and pest monitoring mechanism.
3. Implementing continuous pest management strategies.
4. Developing staff capacity / training.
5. Conducting regular awareness programmes.
6. Developing laboratory facilities.

1. **Strengthen quarantine measures for risk mitigation**

Plant quarantine measures play a crucial role in risk mitigation of pests and diseases. Different countries have developed their own regulations and guidelines in importing plant material and their post quarantine requirements.

In Maldives, a Plant Quarantine Regulation is in place and the authority to carry out the regulation is vested to the Plant and Animal Quarantine Unit operating under the Ministry of Fisheries, Marine Resources and Agriculture. According to the Regulation 9a, coconut plants is prohibited to be imported to Maldives. However, it was understood that coconut seedlings and plants are being imported to the country by the Government and resorts.

There are many serious pests and diseases of coconut reported worldwide. Some of those are serious and invasive (e. g. red palm weevil, coconut leaf eating caterpillar, coreid bug, locusts etc.). More importantly, some diseases caused by viroids and phytoplasma are of incurable nature (e.g., Coconut wilt disease in India, lethal yellowing in the Caribbean and Africa). Currently, in Maldives, only *Brontispa* beetle and whitefly are recorded as serious pests while no diseases are yet reported. Therefore, it is essential to protect the coconut industry of Maldives from invasion of serious pests found elsewhere. Many of these pests have a wide range of host plants, especially species in the family Palmae. Hence, attention must be given not only coconut, but also importation of palm species too.

An island country like Maldives can be easily protected from coconut pest invasions because the most probable mode of entry of pests is through importation of coconut and allied palm material. Hence, strict quarantine regulations and post quarantine measures could prevent such introductions.

There are many different forms of coconut in Maldives, bearing large and considerable number of nuts. For planting in the country, existing palms with desirable characters could be selected as mother palms. Seed nuts could be collected from these mother palms for seedling production. If this is carried out there would be no need to import coconut seedlings for planting purposes, which prevent the risk of pest invasions. However, if there is a necessity to import coconut seedlings or other palm species it should be done under strict quarantine measures.

With respect to importation of coconut and other palm species the following recommendations are made.

1. Conducting a Pest Risk Analysis (PRA) of the plant species to be imported.
   Pest risk analysis (PRA) is a scientific process that evaluates the potential for the introduction, establishment, and spread of pests in a particular area. It is used to identify and assess the risks

associated with the movement of plants, plant products, and other regulated articles. PRA is essential for preventing the introduction of invasive species that can cause significant economic and environmental damage. It is also used to develop appropriate measures to manage the risks associated with the movement of regulated articles. For example, PRA can be used to determine whether a particular plant species should be allowed into a country or whether it should be subject to quarantine measures.

This is the essential first step in importation of palm species and even other species of plants. PRA involves a series of steps. The procedure and guidelines in conducting a PRA is provide by the FAO (Pest risk analysis for quarantine pests, 2017). PRA should be carried out for each palm species importing from each country, if not done previously. Since this is a scientific process and if Maldives has no competent person to carry out PRA it is recommended to obtain services of competent personal overseas. PRA should be carried out after the request for an importation is received by the Plant and Animal Quarantine Unit to determine whether the importation is allowed, and if allowed the conditions to be imposed in the phytosanitary certificate from the importing country.

Generally, the conclusions of PRA are a). complete embargo/prohibition: when the pest risk is very high, the safeguards available in the country are not adequate and, therefore, import is prohibited. b). post-entry quarantine: the risk is very high but adequate safeguards in the form of post-entry isolation facilities are available. c). restricted: pest risk is not high and import permit is required stipulating conditions for entry, inspection, and treatment. d). unrestricted: import permit is not required, and material may enter without restriction.

2. Laying out conditions in phytosanitary certificate

Once the PRA is completed, in situations of (b) and (c) above the quarantine authority of Maldives must lay down all the conditions to be adhered in importing palm sp. to minimize risk of associated pests/ diseases.

a. It is recommended that Maldives request fumigation of plants at the port of loading in the country of exporting.
b. It is recommended to continue requesting that the plants are free from disease causing agents.
c. It is recommended to request confirmation that palms are free from disease caused by viroids and phytoplasmas. This could be ensured by requesting a laboratory analysis report issued by an accredited laboratory.

d. It is best that seedlings could be brought without any soil as soil can inhabit harmful organisms. For this, seedlings just sprouted could be imported and then planted in grow bags in Maldives or preferably seed nuts could be imported.
e. Since organic manure could contain various stages of harmful insects, strict phytosanitary conditions must be imposed such as fumigation.

3. Post entry quarantine conditions

Currently the imported coconut seedlings are physically examined for any pests or diseases and kept in open environment thereafter. In general, in other countries plants are kept in confined conditions in insect proof houses and observed for few weeks before they are released to open areas. By this way escape of any accidental introduction of pests and diseases with the importations could be prevented.

Maldives must strengthen its post entry quarantine measures by improving required facilities. This includes constructing insect proof houses for retention of imported plant material in the post entry quarantine period. It is recommended to design and construct the facility complying to the international standards. The publication of International Plant Protection Convention (IPPC) of the FAO in 2016, "ISPM 34 Design and operation of post-entry quarantine stations for plants'' provides guidelines on this. It is recommended that Maldives sought expert assistance in developing post entry quarantine facilities and training staff to undertake the operations satisfactorily.

4. Since Maldives consists of a chain of islands internal quarantine measures plays a major role in preventing spread of any exotic and indigenous pests within the country. This could be done by imposing regulations time to time according to the type of pest and its spread. These regulations may include prohibition of transporting infested plants/ part of plants from an infested area to another.

5. There is a possibility that passengers bring seedlings of ornamental palms in their baggage. To prevent any risk of entering harmful peats/ diseases it is important to make the passengers aware of this. It is recommended to display sign boards in the international airports regarding it.

2. Pest Surveillance and Monitoring

Despite strict quarantine measures there are remote chances that pest/ disease could be introduced into the country by other means such as through passenger baggage and by imported

plants that harbor pests / diseases of coconut. In such cases pest surveillance is essential to detect occurrence of exotic pest/disease in the early stages of their introduction to adopt and enforce domestic quarantine regulation to ward off their further spread. Hence, a mechanism must be in place for pest surveillance combined with pest monitoring in each Council area since the Councils has the responsibility in pest management in their respective areas.

The following is recommendations are made.

1. Establish a "Coconut Development Unit'' under the Ministry of Fisheries, Marine Resources and Agriculture as the focal point to deal with all coconut development related matters. Initially assign 2 - 3 officers from the Ministry to provide directives, technical advice, and training. They will closely collaborate with Councils on pest/ disease matters.
2. These Officers must get a thorough training and hands on experience on coconut cultivation (including pest management).
3. Since the responsibility of pest management lies with the Councils (from 2019), the Councils need to develop suitable mechanisms for surveillance, monitoring the status of pests/ damages as well as pest management.
4. Identify 1-2 officers from each Council to deal with coconut related matters, including pest management and to directly liaise with the Coconut Development Unit. It may be convenient to identify 1-2 officers for a group of Councils, if the Council area is small or suitable officers are not available.
5. Train possibly one officer from each council overseas (with coconut growing area).
6. These trainers could train other officers/ public in the Council time to time.

Regular surveying of the Council area is recommended for surveillance, pest monitoring and pest management. Presently, the officer/s attention should be given on infestations of whitefly, hispid beetle and *Oryctes* beetle and rat damage.

It is recommended that these officers;

a. Survey the coconut area belonging to the Council at regular intervals and observe and record pest status. If unknown/ previously not observed pest/disease is observed on coconut notify the Coconut Development Unit.
b. The procedure of conducting the survey on whitefly and hispid beetle infestations are given under respective pest.
c. Conduct awareness programmes to the residents, time to time and request their assistance to identify new areas of infestations/ status of damage etc. (handouts on each pest is attached).
d. Obtain assistance and advice from the focal point when necessary.

e. Report the actions taken and pest status to the Focal point every 3 months.

3. Implement pest management strategies

Once a pest invades a country it is extremely difficult to eradicate it. Pest populations may vary largely with climatic conditions in addition to other conditions. Hence, keeping the pests below economically damaging level is the best option in coconut pest management. The recommended pest management strategies for the pests prevalent in Maldives is given below.

Whitefly (RSW and BNW)

Out of the methods available for the management of RSW and BNW, considering the situation in Maldives it is recommended using botanical insecticides (neem oil and soap mixture), only when necessary, and releasing parasitiods, if field parasitism is absent or very low.

Method of preparation of neem oil solution;
Dissolve 10 ml of neem oil, 5 g. of soap powder in one liter of water to prepare the solution. Spray the leaves, especially the lower ones thoroughly with about 3 - 4 liters of solution. Spraying should be carried out in the evenings as neem oil is photosensitive. Do not spray on rainy days.

Biological control using parasitoids provides a sustainable solution for management of RSW and highly recommended. Since, naturally occurring parasitoids are found in many islands infested with whitefly, it is essential to conserve them and augment with laboratory bred parasitoids wherever necessary. Although, several parasitoids are recorded elsewhere, currently no country is producing them at a commercial level. Therefore, obtaining large quantities of parasitoids for field release in Maldives would not be possible. Hence, the only option is to mass rear the parasitoids in the Maldives itself. Like natural enemies of other pests, these parasitoids too would follow the population levels of the pest naturally. However, augmentation of these parasitoids by mass production and release will enhance the parasitism levels and early control of RSW. Hence, it is recommended to initiate a programme in mass production of parasitoids collected from parasitized RSW in the field.

In deciding on augmentation of parasitoids it is important to regularly monitor the pest infestation. Guidelines for the pest and natural enemy assessment is given in Annex 4. Although, release of parasitoids may not give immediate control of the pest, it would gradually reduce the pest population sustainably. Establishment of a parasitoid breeding facility, methodology of mass breeding and release of parasitoids is given in Annex 5.

A leaflet on biology, damage symptoms and natural enemies of RSW which is the predominant whitefly species is given in Annex 6 for the awareness of officers and public.

Hispid beetle

In Maldives, it was observed that hispid beetle damage varies from low to moderate damage. In some coconut growing islands it was not present. Since chemical treatment of palms is impractical, it is recommended to release parasitoids for its management. It is strongly recommended to re-start the mass rearing programme of parasitoids as required equipment, facilities and methodology are already available in the Quarantine Unit of the Ministry. If staff training is required, the government may get assistance of governments of Thailand/ China/ Vietnam. This method is more economical than importing parasitoids from overseas in the long term. Since parasitoids take a certain period to establish and exert control over the pest it is also recommended to continue periodic release (every 2 months) for at least 2 years.

***Oryctes* beetle**

The management of *Oryctes* beetle is described in the Advisory Leaflet in Annex 7.

Rats

The management strategies for rats are described in Advisory Leaflet in Annex 8. Rodenticides currently available in Maldives could be used in baiting.

4. Awareness programmes

The proposed Coconut Development Unit could undertake awareness programme with the assistance of councils. The following actions are recommended.

a. Distribution of handouts/ advisory leaflets of management of different pests (use Advisory circulars in Annexes)
b. Carry out regular awareness programmes and demonstrations on pest management by councils to public in all coconut growing islands.
c. Conduct regular radio and television programmes.
d. Obtain the participation of public in pest management activities of the council.

5. Develop staff capacity / training

It is extremely important that officers handling coconut related matters have adequate knowledge and training to carry out pest surveillance, monitoring and pest management activities. Currently, this knowledge is largely lacking among Agricultural Officers and Council Officers. Also, the public is totally unaware and negligent of pest damages and the economic losses it would cause as there no officer to guide them.

A special training programme could be designed in an overseas country such as Sri Lanka, on the request of the Government of Maldives. Such a training programme will be highly beneficial to get knowledge and first-hand experience and therefore strongly recommended.

Currently, there are no trained agriculturists or entomologists with the Ministry to take immediate measures when pest management is required. It is suggested that 2 -3 officers of the Ministry be trained up to diploma, graduate level, and preferably post graduate level.

6. Develop laboratory facilities

In long term, Maldives could develop their own laboratory facilities to carry out preliminary entomological work. This could include insect rearing facility and screen houses. This facility could be further extended, as required to house the Coconut Development Unit.

Laboratory

Basic sketch of a laboratory building is given below. It consists of an entomology laboratory and insectary. Insectary could be used to carry out RSW rearing activities. The insectary door should be in double to prevent any insects getting in and out. In the entomology laboratory, pest management laboratory work be undertaken.

Basic requirements of an entomology laboratory are;
Stereo binocular microscopes with light sources, light microscope, fridge, incubators, water still.
Laboratory furniture, racks, glassware (test tubes, cylinders, conical flasks, beakers, glass slides and coverslips, cavity glasses, forceps, scalpels, Pasteur pipettes, pipettes, reagent bottles, plastic trays, insect pins, camel hairbrushes, glass tubes, plastic containers etc.).
Chemicals (ethanol, chloroform, stains, KOH, distilled water, reagents as necessary etc.).

Screen house

It is suggested to construct 2 screen houses of 3 m x 3 m with double entry doors. The screen house should completely cover with insect proof netting and roof with clear polypropylene or glass. These screen houses could be used for mass rearing of RSW. One cage could be used to rear mother culture of RSW and the other to rear parasitoids.

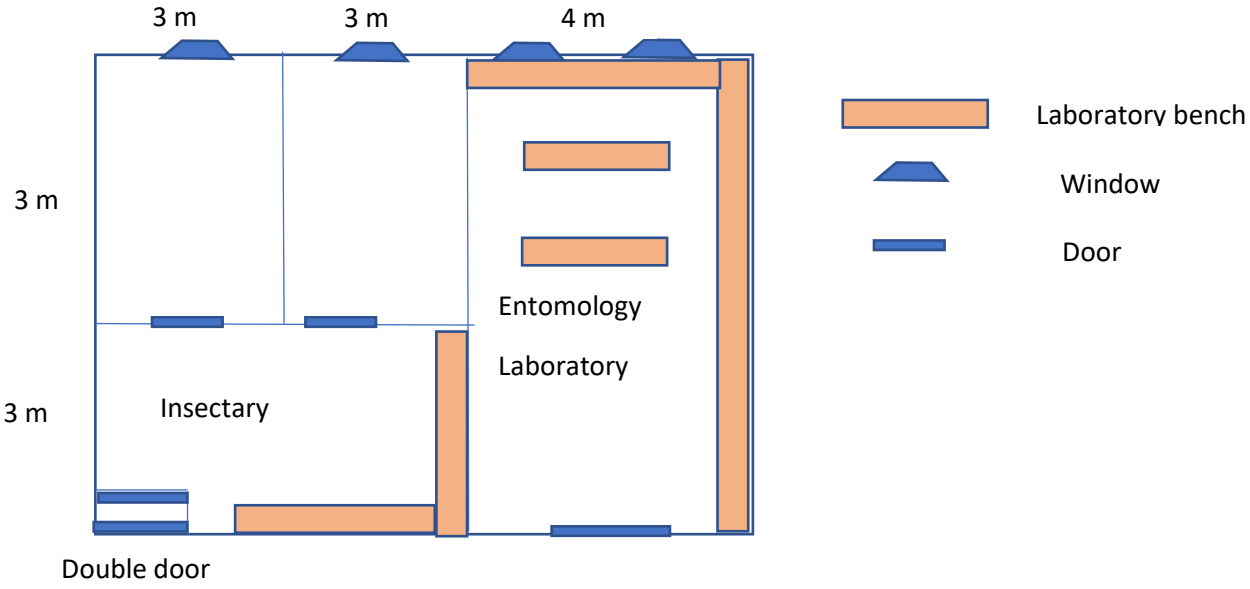


Figure 17. Sketch of a floor plan for an entomology laboratory and insectary

POSSIBLE VALUE-ADDED PRODUCTS AND MEDIUM- AND LONG-TERM INTERVENTIONS TO INCREASE REVENUE FROM THE COCONUT INDUSTRY, SUPPLY AND VALUE CHAIN MAP OF COCONUT-BASED INDUSTRY IN MALDIVES AND IDENTIFIED CRITICAL NODES

Demand for coconut in the Maldives

Coconut is a highly demanded food commodity in Maldives. The existing information indicates that the supply of fresh coconut was sufficient to meet the coconut demand of the country, except in 2022 and 2023 during which supply shock occurred due to whitefly attack along with other factors. However, demand for coconut is further increasing with the increasing population and reducing of coconut lands. Demand for coconut in the Maldives are for mature coconut for consumption, half-mature coconut for manufacturing sweets, young coconut for drinking, coconut oil, coconut timber for construction and cadjan for roofing.

Table 6 shows the existing value-added products in Maldives and its potential for expansion.

Table 6. Existing value-added coconut products and potential for expansion

Existing coconut products		Potential for expansion – Short Term	
Young coconut Coconut oil Masala Coconut honey	Small scale	Young Coconut water Young Coconut Water Bottling Virgin coconut oil Coconut paste Coconut flour Coconut oil Masala Coconut Toddy Coconut honey Coconut Sugar Coconut Treacle	Commercial scale
Coir fiber Coir pith Coir twine	Very small scale	Coir fiber Coir pith Coir twine	Medium scale
		Potential for expansion – Long Term	
		Desiccated Coconut Spray Dried Coconut Milk powder Activated Carbon	

World demand for coconut water, sugar and oil

Niche coconut products are surging in popularity, as shown in Fig. 18. Due to the discovery of many health benefits of coconut in recent years many affluent consumers use coconut products as a component of their diet. Coconut water business in the US has surged in value from a few million dollars a decade ago to nearly $800 Mn in 2015. Globally, the coconut water industry alone was able to generate $4 billion in revenue between 2015 and 2019. Coconut milk sales are escalating rapidly too; in the US,

coconut milk sales rose by 35% in 2015 to approximately $27 Mn, and in the UK, they grew by 67% (Cuckoo for Coconuts, 2016).

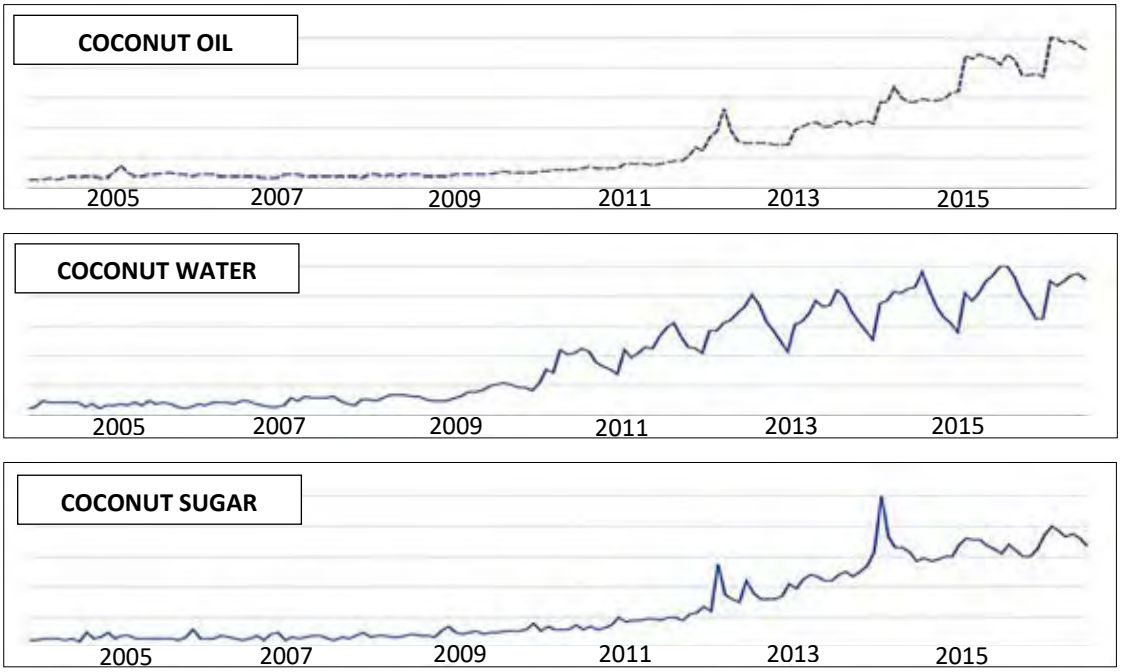


Figure 18. Demand for coconut oil, coconut water, and coconut sugar in the world market (2006-2015) (Source:http://www.centrafoods.com/blog/supply-and-demand-in-the-coconut-oil-market-market-update)

PROPOSED VALUE–ADDED PRODUCTS

1. Tender Coconut Water

Tender coconut water is an eco-friendly refreshing drink. It is rich in vitamins, minerals proteins, amino acids, sugars, and other biological growth factors and enzymes. It is a natural isotonic beverage that has almost the same level of electrolyte balance as in our blood. It is the 'fluid of life' that promotes anti-aging, healthy cell growth, and rehydration. Tender Coconut Water serves as a mineral drink with therapeutic properties that help in regaining the vitality of the human body. The characteristic flavor of tender coconut is contributed by delta lactones. Glucose and fructose form important constituents of tender nut water. Glucose is highest at the seventh month of nut maturity. Tender Coconut Water contains most of the minerals such as potassium, sodium, calcium, phosphorous, iron, copper, magnesium, etc. The contents of arginine, alanine, cystine, and serene in the protein of tender coconut water are higher than those in cow's milk. It also contains vitamins C and B groups. Tender coconut is a more popular drink in Maldives and is served in fresh form.

Tender coconut sales are the most popular and has a significant share in the wholesale market in Male as shown in the Table 7.

Table 7. Statistics of Coconut Sales in the Male Wholesale Market

	2022 (MVR)	2023- Jan to July (MVR)
Annual matured coconut sales	844,760.00	639,114.00
Annual tender coconut sales	5,306,070.00	1,162,510.00

Processing of tender coconut and coconut water from matured coconuts is given in Annex 9.

2. Coconut water from matured coconuts

As the coconut matures, the water is replaced by coconut meat. Coconut water is rich in carbohydrates and electrolytes such as potassium, sodium, and magnesium. Because of these electrolytes, there is lot of interest in using coconut water to treat and prevent dehydration. Coconut water is one of the best for rehydration; it is high in potassium, low in calories, and completely free of fats and cholesterol. Small-scale coconut water collection, preservation and bottling is given in Annex 9.

3. Virgin Coconut Oil (VCO)

There is a high potential in Maldives for manufacturing of VCO. It has multifunctional uses such as using as a food supplement to boost immunity system, cure dementia, and many other health benefits. It can be used in production of cosmetic soaps blended with flower essence, skin care products, therapy massages, body lotions, and hair and skin conditioners. The by-product from virgin coconut oil could be further processed into coconut flour.

Wet processing of coconuts is a new process of oil extraction from fresh matured coconuts for producing high-value and high-quality VCO, rich in vitamin E and possessing a long shelf-life period of one year. This technology is capable of complete utilization of the coconut. Apart from virgin coconut oil, several other value-added coconut products like coconut milk, low-fat coconut powder, skim milk, and packed coconut water could be developed from this process. One liter of Virgin Coconut Oil (VCO) is obtained from 12 fully matured, fresh coconut kernel by mechanical or natural means with or without application of heat which does not lead to alteration of the oil and its properties. VCO can be produced from fresh

coconut kernel or coconut milk. Different production processes are adopted depending upon the scale of operation, degree of mechanism, and investment available.

Annex 9 gives the procedure of production of VCO as a cottage industry.

4. Coconut oil

Use of coconut oil as a cooking oil is popular in Maldives for a long period of time. It is predominantly used for manufacturing of soap, glycerine, margarine, and cosmetics. Coconut oil along with palm kernel oil are the only sources of short-chain fatty acids. Therefore, it is highly sought after by industries for its high Lauric acid content of 48%. The manufacturing process of coconut oil is given in Annex 9.

5. Coconut Cream, coconut paste and coconut flour

Coconut cream is a white, smooth, liquid cream with an excellent coconut flavour with 20 - 30% of fat content, aseptically packed. The product is easily pourable and ready for direct serving or to be used in food preparations. For normal household uses, coconut cream is diluted with water.

Coconut paste could be stored up to 6 months in normal conditions. Its production is given in Annex 9.

After expelling the milk, the protein-rich residue is dried and powdered to obtain a product called coconut flour. The flour contains 7% - 8%t protein, 3% - 5% moisture and 17% oil. It can be used as an ingredient in weight control foods because of its high fiber content. The protein contained in the flour is identical to that contained in the original fresh kernel. After blanching the residue is dried and passed through a special type of screw press under a specified expeller setting to reduce oil content without too much change in colour. The de-fatted flakes are re-dried to reduce their moisture content to 2.5%- 3%, which is finally ground to a fine mesh.

6. Coconut Toddy, jaggery and treacle

The sap from the young inflorescence is called toddy. The sap has a high sucrose content varying from 12% - 17% depending on the cultivar. It is obtained by tapping the inflorescence before splitting of the inner bract and emergence of the spike from the spathe. The word tapping collectively refers to the extractions and various manipulations like tying of the spathe beating the spadix, bruising, and rupturing the tender tissues of the floral bract by hammering and pounding the spathe, and slicing the apical tissue. The interval from the beginning of the tapping to the dripping of the toddy varies from 5 days to 32

days. Tall cultivars yield more sap than dwarf palms. Yield varies from 1.5 to 2 l per day. Under natural conditions, toddy is fermented by the native microflora consisting of yeast and bacteria. This process will take place from the time when sap comes out and contacts the air. To reduce the rate of fermentation, traditionally, lime is added to the collecting container, usually in a clay pot.

Coconut sap-based products such as coconut sugar/jaggery, beverages, toddy, and vinegar are gaining much attention mainly due to their beneficial properties. Coco sugar's glycaemic index is low at 35 which can be taken both by normal and diabetic patients. Coconut sugar also contains macro and micronutrients as well as essential vitamins. Most of the producers are small to medium-scale village-level operations. Coconut-based alcoholic beverages particularly, coconut arrack, coconut vodka, and coco wine, have also gained popularity in the major coconut-producing countries.

7. Coconut Ice Cream

Coconut ice cream is very popular in Thailand, China, Sri Lanka, and other countries This is made up of 100% pure coconut milk. This is suitable for lactose intolerance and vegetarians**.** The production process is given in Annex 9.

8. Coconut Yogurt

This is a very good substitute and nutritious product for imported yogurt. See Annex 9 for production process.

9. Coir pith

Coir pith is the by-product obtained during the extraction of coir fiber. It is an excellent soil conditioner, rooting medium, and mulching material. Pith constitutes about 70% of the husk itself. Coir pith which is known as coco peat has a growing market in the world for use in horticulture/agriculture. It has been used in many islands for vegetable cultivation. The coir peat is manufactured on a small scale in few Islands and the balance is being imported from surrounding countries. Most coconut husks are unused and can be extensively used to manufacture coir and coir peat.

10. Coir fiber and twine

Coconut husk is the raw material for the coir industry. It is also used as a domestic fuel and as fuel in copra kilns. It is used in coconut gardens to conserve soil moisture besides being used as a surface mulch in coconut basins. The husk of the mature coconut consists of numerous fibers embedded in a soft cork-like ground tissue usually referred to as pith. The fibers are 15 t- 35 cm long and have a high tensile strength which is unaffected by moisture. It has varied uses on account of its natural resilience, durability, and resistance to dampness and other properties. The manufacture of coir and coir products is a highly labour intensive covering a wide range of activities including the collection of husks, retting, fiber extraction, spinning, and manufacture of coir and coir products. The two major coir-manufacturing methods are mechanical de-fibering and traditional retting processes.

11. Coconut shell charcoal

Coconut shell charcoal is manufactured by burning shells of fully matured nuts in a limited supply of air sufficient only for carbonization, but not for complete burning. The output of charcoal in the traditional pit method is just below 30% of the weight of the original shells. Shell is converted to shell charcoal by carbonization process in mud pits, brick kilns, and metallic kilns. To obtain good quality charcoal, fully dried, clean, mature shells should be used. Several modern methods are in practice to produce charcoal. In the modern waste heat recovery unit, the heat generated by the burning of coconut shells is used for drying copra, and shell charcoal is obtained as a by-product. This process can be recommended for the Maldives cottage industry in par with copra production.

12. Coconut shell powder

The coconut shell powder has extensive uses in plywood and laminated board industries, as a phenolic extruder and as a filler in synthetic resin glues, and mosquito coils. Coconut shell powder is preferred as a substitute for bark powder, furfurole, and peanut shell powder because of its uniformity in quality and chemical composition. It also has better properties in respect of water absorption and resistance to fungal attack. Coconut shell powder is manufactured from matured coconut shell by using pulverizes / ball mills. About 12,000 shells would yield around one ton of shell powder.

13. Coconut wood products

The high-density wood of the outer portion of the stem is quite strong. Low-density wood of the central core is soft and therefore it is used as fuel. Coconut wood is traditionally used for making roofing components like rafters, joists, purlins, beams, banisters, etc in coconut growing areas. It is also used

for the construction of temporary sheds, cow sheds, workshop buildings, farm buildings, small rural bridges, etc. Only the first 8 to 10 m of the mature tree is good for making doors, windows and furniture. About 0.15 – 0.2 m^3 sawn sizes could be obtained from an average size fully mature tree. The timber of coconut palm, because of the lasting grains excels than other woods in beauty. The timber is also suitable for carved decorations. Coconut wood is also used to make wall panels, floor tiles, and handicrafts.

Proposed value-added products for long-term commercial level production

1. ***Desiccated coconut***

Desiccated coconut is the white kernel of coconut, disintegrated and desiccated to a moisture content less than 3%. It is a popular commercial product having demand all over the world in the confectionary and food industries as one of the main subsidiary ingredients of fillings for chocolate, candies, etc. It is also used uncooked, as decoration for cakes, biscuits, ice cream, and toasted short eats. Common grades of desiccated coconut like granulated and fancy cuts like flakes, treads, etc. are popular. Granulated cuts include coarse medium fire and superfine grades.

2. ***Spray dried coconut milk powder***

Coconut milk powder is the dehydrated form of coconut milk. This product has a high keeping quality and retains the natural flavour, texture, and taste of coconut milk. The process of making coconut milk involves deshelling, paring disintegration of the kernel, squeezing the kernel in a screw press, standardization of coconut milk with maltodextrin and sodium caseinate, pasteurization spray drying and packing in aluminium packets. The powder is easily dissolved in water to form a milky white liquid. with the flavour and texture of coconut milk (Muralidharan, 2019).


3. Activated Carbon

Activated Carbon is a non-graphite form of carbon that could be produced from any carbonaceous material. Coconut shell-based activated carbon is considered superior to those obtained from other sources due to its small macro pore structure which renders it more effective for the adsorption of gas/vapor and for the removal of colour and odour of compounds. It is widely used in the refining and bleaching of vegetable oils and chemical solutions, water purification, recovery of solvents and other vapours, recovery of gold, and in gas masks for protection against toxic gases. On average 3 tons of coconut shell charcoal would yield 1 ton of activated carbon.

Medium and long–term interventions needed to increase revenue from the coconut industry in the Maldives

Many gaps are found in the supply and value chain of the coconut industry in Maldives resulting in low nut production and revenue. The supply and value chain that prevails in the traditional coconut industry indicated the urgent necessity for enhancing productivity through improved technologies and better coordination with the island councils and the Ministry, especially in procurement and use of inputs and community-level processing of coconut. Organizing coconut and other agricultural farmers and empowering them to make appropriate decisions on the adoption of technologies from cottage industry to high-technology production, purchase of inputs collectively and distribute their products to get a price advantage are necessary. Thereby farmers will be able to move in the value chain. Further, the conventional extension system is not fully equipped to meet this requirement. The supply and value chain initiation would be the benchmark for formulating strategies toward industry prospects.

Supply and value chain interaction in the Maldives context

A value chain is the collection of actions required to move a product from the producer to the final customers. The value chain includes all events such as procurement of input, processing, transformation, and promotion until the final consumption and disposal. The coconut value chain is extremely complex due to the many products that can be derived from the coconut palm. From its roots, trunk, leaves, and the different components of its nuts, husk, shell, kernel, and water, parts of the tree can be used for housing, wood energy, furniture, handicrafts, other functional utilities, and food. Many of the value chain actors undertake more than one function spanning more than one sub-sector. On the other hand, supply chain actors are inter-winding with the value chain and providing many pathways to reach the end customers (Figure 19).

Critical Nodes of the Coconut Industry in Maldives

The coconut production was one of the crops that had boosted Maldives' economy in the past. However, it was revealed that coconut production has been reduced drastically. According to the observation made by the FAO consultants during the visit to many islands observed that the cause for this is mainly due to the negligence of maintaining coconut cultivation, especially belonging to the island councils and government institutions. This situation caused interruptions in the sustainability of the Maldives' supply chain of coconut. Therefore, the development of an immediate long-term plan for its revival is essential. Lack of education and training in rural areas keeps farmers with a very low knowledge base in Agri-technology. The coconut output in the islands was hampered by poor agronomic practices, lack of inputs, and lack of extension services, among other factors inferior varieties pests, disease attacks, land, and political and socio-economic features can contribute to low coconut production. Most of the coconut cultivation being maintained by the council and government institutions have not paid any interest to generate income from the property. The land productivity of the monoculture coconut is very low and very few farmers are interested in growing intercrops under coconut. The challenge with nut collection, the high transportation cost for marketing and lack of interest paid by the government for the development of the sector further hampered the industry. The lack of labor, inadequate facilities and poor infrastructure is impacted for the value addition. The other critical node encountered by the farmers is the price fluctuation of the coconut in the islands, and the Male market.

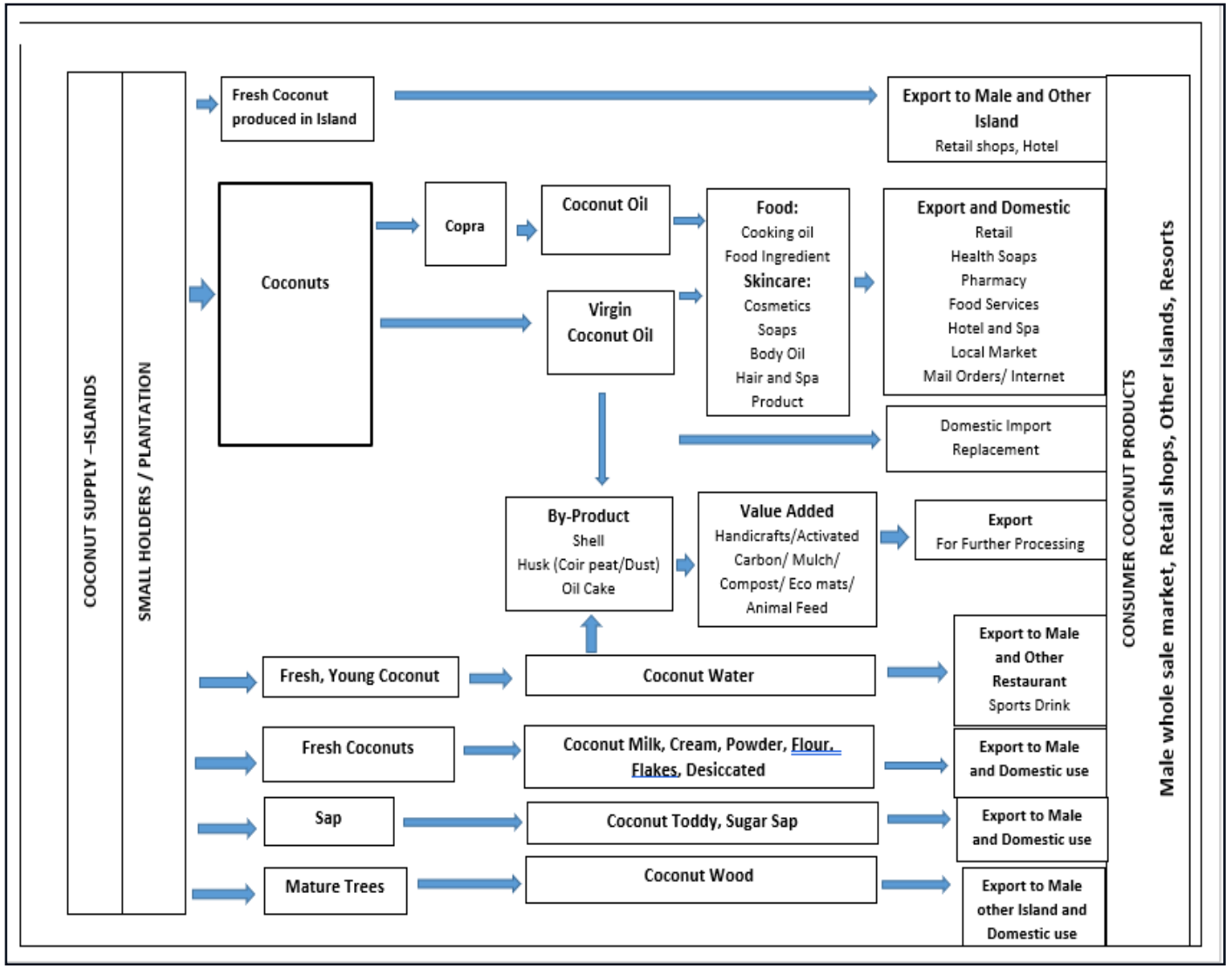


Figure 19. Supply and Value Chain Maps of the Coconut-Based Industry of Maldives

Strategies and interventions to support the infusion of identified techniques in adding value to the coconut industry in Maldives

Feasibility studies

To choose the most beneficial products for value addition, it is necessary to conduct a feasibility study (Table 6). According to the observation made by the consultant, the coconut ice cream, virgin coconut oil (VCO) and white coconut oil (WCO) (white coconut oil is produced by using of dryer instead of copra kiln to minimize the contamination and improve the quality) as the most potential products for Maldives. According to the results in Table 6 all three projects are financially viable in Sri Lankan condition. These results can be adopted to the Maldives with few adjustments. Out of the three projects, coconut ice cream generates the highest benefits over other two products, virgin coconut oil generates 55% IRR and white coconut oil generate 44% of IRR (see Annex 10 for details of cash flows).

Table 6. Summary of the feasibility study for potential value addition projects

	Coconut Soft Ice Cream (No. of Cones)	**VCO (Liters)**	**WCO (Liters)**
Production/Year	1,000,000	50,000	60,000
Income/Year (Rs.)	70,426,000	61,375,000	59,760,000
Total Expenditure/Year (Rs.)	40,257,600	43,989,925	45,189,925
Gross Margin (Rs.)	30,168,400	17,385,075	14,570,075
IRR	132%	55%	44%
NPV	35,468,543	24,516,862	17,513,632
BCR	1.40	1.29	1.22

IRR: Internal Rate of Return, NPV: Net Present Value, BCR: Benefit Cost Ratio

Interventions to develop industry potential for coconut and coconut-based products

The following interventions are suggested.

- Removing supply chain bottlenecks to ensure a steady supply of raw material.
- Strategically investing in Research and Development for new product development and innovations
- Continuous process improvement
- Quality enhancement

- Upgrading plant, machinery, and warehouses
- Skill development

Other agriculture interventions and strategies to improve the coconut value chain

The main problem in coconut development is that the management of coconut cultivation is still traditional, and the quality of the products is still low, so coconut commodities that are multipurpose, relatively have no added value. The economic value of coconut is still dependent on primary products, namely coconut, young, coconut and copra. To increase farmer income the solution that can be taken is to implement the value chain in integrated coconut farming by diversifying coconut products. Several obstacles could arise in the development of the value chain, including the lack of farmer participation in the modern chain, weak market power and market access, weak contractual relationship strength, and weak agricultural sector development orientation, etc. These issues can be managed with interventions by the government, line ministries and islands councils. Managing an integrated coconut farm with many intercrops can increase financial and economic benefits (Samarakoon *et al.*, 2023). The output of the diversified crops can be blended with coconut value addition.

Obtaining maximum added value from coconut farming requires collective action through product sales, purchasing production facilities, investment capital as well as access to information about new technology. The island councils support to activate the coconut oil industry at the farmer group level is essential. Also, supporting farmer groups in purchasing coconut oil, coir and coconut ice cream production machinery along with the government initiatives would help to improve the revenue of farmers. Obtaining the Geographical Indicators (GI) for Maldivian products will greatly contribute to enhance the sales. In addition, strengthening the farmer groups to increase bargaining power and reduce transaction costs in marketing and at the same time enhancing vertical coordination by creating a network of partnerships with market participants and honoring contractual agreements in profitable markets would be beneficial interventions.

STRATEGIC PLAN FOR REVITALIZING OF COCONUT SECTOR IN THE MALDIVES

Objective	Strategies	Activities		
		Immediate/ Short term (less than 1 year)	**Medium term (1-3 years)**	**Long term (over 3 years)**
1. Increase coconut production	1. Increase nut production in plantations/ coconut holdings neglected of management for many years (palms in mid age, planted in a square system)	1. Identify locations of lands. 2. Carryout clearing of under growth. 3. Conduct palm census. 4. Identify and mark palms require rehabilitation. 5.Commence adoption of recommended management practices. 6. Identify and remove palms which are beyond recovery stage. 7. Fill all vacancies with high quality seedlings.	1. Continue adoption of recommended management practices to bearing palms. 2. Continue recommended management practices for seedlings and young palms.	1. Continue with required management practices to maintain high level of nut production and high growth standard of seedlings.
	2. Increase nut production in neglected plantations/ coconut holdings which can be	1. Identify the locations of lands. 2. Clear under growth among palms. 3. Conduct palm census.	1. Mark and dig planting holes in the center of the square of old palms.	1. Continue with standard management practices required for seedlings.

	underplanted (with a mixture of palms in different ages and production categories and originally planted with a square system roughly with 24’ x 24’ distance)	4. Acquire required number of high-quality seedlings. 5. Identify weak, unproductive, diseased, senile palms and remove.	2. Carry out underplating correctly with high quality seedlings, with the same distance and density as per the old plantation. 3. Commence adoption of recommended management practices for seedlings.	2. Carry out periodical thinning of old palms, up to five years.
	3. Rehabilitate (replanting) neglected unproductive plantations/ coconut holdings which cannot be underplanted (with very weak, senile, closely planted and not feasible to increase nut production)	1. Identify locations of lands. 2. Remove all coconut palms and clear the entire land area. 3. Acquire the required number of high-quality seedlings for replanting the full extent.	1.Line to mark planting points based on the density required for different types of coconut (tall or dwarf). 2. Open planting holes and prepare planting by adding fertilizer and organic matter. 3. Commence field planting of seedlings and after care operations as recommended.	1. Continue management of replantation as per the technical recommendations, up to flowering stage.
	4. Increase nut production in high density plantations/ coconut holdings (low nut production, high	1. Identify locations of high density and close-planted lands. 2. Clear undergrowth in between palms.	1. Thin out excess palms based on the guidelines provided. 2. Commence adoption of recommended management	1. Continue adoption of recommended management practices to improve palm health and their nut production.

	density and neglected management)	3. Carry out a field survey to identify and mark palms to be removed to bring down the palm density as per the guidelines provided.	practices to improve palm health and their production.	
	5. Increase extent of coconut cultivation	1. Plan cultivation of coconut in home gardens. 1. Plant and manage coconut seedlings on roadsides.	1. Plant and manage coconut along the boundaries of agricultural lands.	1. Plant coconut in unutilized open lands and lands reclaimed sites. 2. Plant coconut in water logging and large marshy lands.
	6. Provision of high-quality planting material required for planting programs	1. Select mother palms from existing tall coconut plantations/ holdings. 2. Select mother palms from existing dwarf coconut plantations/ holdings. 3. Select seed nuts for laying in nurseries. 4.Produce high quality tall and dwarf seedlings in nurseries. 5. Select seedlings and issue for field planting programs.	1. Continue selection of tall and dwarf types of mother palms. 2. Continue producing high quality tall and dwarf seedlings in nurseries. 3. Select seedlings and issue for field planting programs	1. Select a large mother palm pool combining all islands for production of seed nuts for national programs. 2. Establish a network of coconut nurseries within islands to cater the entire seedling requirement of the country.

	7. Increase nut production by reducing water stress	1. Adoption of soil moisture conservation practices in adult and young plantations/ holdings. 2. Promote application of organic manure to enhance water holding capacity. 3. Apply water for adult and young palms.	1. Continue adoption of soil moisture conservation practices in adult and young plantations. 2. Continue promotion of application of organic manure.	1. Continue adoption of soil moisture conservation practices in adult and young plantations. 2. Continue promotion of application of organic manure.
	8. Increase nut production by increasing soil fertility status	1. Apply recommended doses of chemical fertilizer mixtures for both adult and young palms. 2. Enhance soil quality, nutrient levels and water holding capacity by adding organic matter to palms.	1. Continue application of recommended doses of chemical fertilizer mixtures for both adult and young palms. 2. Prepare high quality composts in coconut plantations/ holdings to be applied to coconut	1. Continue application of recommended doses of chemical fertilizer mixtures for both adult and young palms. 2. Continue composting. 3. Recommend fertilizer based on leaf nutrient analysis.
	9. Increase nut production by minimizing mutual competition	1. Manage weeds to reduce competition for nutrients and water.	1. Continue management of weeds.	1. Continue management of weeds.

	10. Encourage coconut palms for more nut setting and production	1. Introduce regular coconut picking cycles in plantations/ holdings. 2. Conduct a training programme for coconut climbers and pickers. By pole. 3. Sell coconuts of council owned coconut. 4. Lease out council owned coconut trees.	1. Continue regular coconut picking. 2. Introduction of coconut climbing machine.	1. Continue regular coconut picking. 2. Connect trees with rope to harvest young coconut and toddy tapping.
2. Increase land productivity	1. Increase land use efficiency in coconut growing areas.	1. Promote correct planting distance and densities. 2. Adopt recommended plantation management technologies. 3. Plant hybrid and dwarf coconut for immature nut production. 4. Promote integrated farming systems in coconut lands.	1. Continue promoting correct planting distance and densities, adoption of recommended plantation management technologies, planting of hybrid and dwarf coconut, carry out and integrated farming systems in coconut lands. 2. Carry out livestock farming in coconut lands.	1. Continue promoting correct planting distance and densities, adoption of recommended plantation management technologies, planting of hybrid and dwarf coconut, carry out and integrated farming systems in coconut lands. 2. Promote hybrid and dwarf coconut in large scale for toddy tapping

			3. Revision of land use policies to encourage coconut cultivation.	3. Continue livestock farming in coconut lands.
3. Reduce crop loss due to pest damages	1. Strengthen Plant Quarantine measures	1. Commence conducting Pest Risk Analysis (PRA) in importation of palm species. 2. Commence imposing strict phytosanitary conditions when importing palms species. 3. Impose internal plant quarantine measures to prevent further spread of RSW.	1.Continue PRA. 2. Continue imposing strict phytosanitary conditions. 3.Construct and use net houses to initiate post entry quarantine activities.	1.Continue PRA. 2.Continue imposing strict phytosanitary conditions. 3.Continue use net houses for post entry quarantine activities.
	2. Implement a pest surveillance and monitoring mechanism	1. Commence monitoring of RSW infestations.	1.Commence regular surveying of coconut areas for pest damages.	1.Continue regular surveying of coconut areas for pest damages.
	3. Implement continuous pest management strategies.	1. Spray neem oil mixture to RSW infested palms, if necessary. 2. Commence mass rearing and release of RSW parasitoids. 3. Commence mass rearing and release of hispid beetle parasitoids.	1. Continue mass rearing and release of RSW parasitoids. 2. Continue mass rearing and release of hispid beetle parasitoids. 3. Spray neem oil mixture to RSW infested palms, if necessary.	1. Continue mass rearing and release of RSW parasitoids, as required. 2. Spray neem oil mixture to RSW infested palms, if necessary.

		4. Implement pest management strategies for rats and *Oryctes* beetle (when necessary).	4. Continue pest management for Oryctes beetle and rats, as necessary.	3. Continue mass rearing and release of hispid beetle parasitoids, if necessary. 4. Continue pest management for Oryctes beetle and rats.
4. Improve dissemination and awareness of coconut technologies	1. Disseminate and enhance use of technologies to increase nut production, land productivity and pest management.	1. Reform the existing extension organizational structure at the national level to achieve the required targets. 2. Establish a "Coconut Development Unit" to handle all matters related to coconut development. 3. Recruit required staff to the Coconut Development Unit. 3. Prepare a comprehensive coconut technology guide. 4. Commence awareness programmes on pest management. 5. Use of print, mass media and digital flatforms to enhance the	1. Continue technology dissemination activities. 2. Continue regular awareness programmes on pest management. 3. Continue planning, implementation and evaluation of targeted extension and technology dissemination programs. 4. Continue coordinating input supplies, services and financial support.	1. Strengthen interactions with other supporting institutions. 2. Establish a mechanism for monitoring, evaluation and impact assessment of field programs. 3. Continue technology dissemination activities. 4. Continue awareness programmes on pest management. 5. Continue coordinating input supplies, services and financial supports.

		knowledge and provision of information to stakeholders. 6. Plan, implement and evaluate targeted extension and technology dissemination programs. 7. Coordinate input supplies, services and financial support.		
5. Collect census of number of coconut trees, extent under coconut and total coconut production in the Maldives.	1. Conduct a survey in all coconut growing areas of the country	1. Conduct a demonstration on numbering and categorizing the trees. 2. Count and mark all coconut trees in smallholder and council owned lands. 3. Collect information on coconut harvest, young coconut harvest, and value-added coconut products from various sources (councils, ports, wholesales, retailers, etc.).	1. Categorize trees by their condition such as bearing, partial, bearing, dead, dud, old, etc.	1. Continue updating the census and total coconut harvest.
6. Improve staff capacity of the Coconut Development Unit	1. Train staff on coconut technologies and pest management	1. Provide short term training to officers assigned to Coconut Development Unit and councils on coconut cultivation, pest	1. Commence graduate and post graduate level training of 2-3 officers in Agriculture and entomology.	1. Continue training of officers.

		management and coconut processing in an overseas country. 2. Train officers on mass rearing of RSW parasitoids. 3. Train 2 officers on mass rearing of hispid beetle parasitoids, overseas.		
7. Improve supply chain network	1. Deliver nuts to manufacturers, suppliers, transporters, warehouses, retailers, and customers consistently.	1. Study the routes for coconut distribution and other facilities 2. Identify and make an awareness program for the wholesalers. 3. Supply fresh and high-quality nuts to suppliers. 4. Network transport from islands to destinations by combining with other agricultural and fisheries products.	1. Develop the infrastructure facilities in the island and Male. 2. Develop the storage facility for coconut /young coconut and value-added products along with other agricultural products on the island-wide and possibly in Male	1. Develop a website with information to manufacturers on the availability of coconut and related products. 2. Network suppliers and producers with a website.
8. Improve coconut value chain	1. Explain the benefits of local coconut-based products and eliminate nodes through better coordination.	1. Customer awareness program 2. Use Social Media website campaigns, Newspaper, and TV Programs. Conduct	1. Print leaflets, advisory circulars, and video clips to further aware of the customers and tourists. 2. Appoint a suitable officer from each council for	1. Continue consumer awareness programmes. 2. Include processing technologies in school and university curriculums, if possible.

		awareness program for council members and other relevant government officials and farmers 3. Choose the possible value-added products by doing a consumer preference study calculate the cost-benefit analysis and compare the outputs. 4. Rank the value-added products for short term, medium-term, and long-term. 5. Identify the location and designing the production facility. 6. Procurement of inputs and transformation the same into output Promote value-added products. marketing and distributing	value-addition intervention including other agricultural value-addition.	3. Continue coordination with the appointed council officers for value-addition development. 4. Prepare an informative information package for value-added products.
	2. Introduce value addition processes and upgrade existing technology to minimize	1. Initially, introduce technologies of Virgin coconut oil, Coconut pastes and Coconut ice cream for	1. Upgrade technology by introducing high-tech machinery and obtaining certification.	1. Further upgrade the process aiming export market.

	wastage (operational productivity).	cottage industries, aiming at Male market and restaurants.	2. Standardize protocols for coconut value-added products.	2. Establishment of a pilot project for coconut value-added products.
	3. Form a community-based organization with other agricultural farmers, involved in coconut cultivation.	1. Connect coconut/ agricultural farmers in islands, collectors, and transporters with the involvement of the council.	1. Improve the land productivity with high-value crops (cinnamon, banana dehydration) under coconut plantation and integrated value addition process.	1. Pack products and label to assure quality.
9. Promote value-added products among Maldivians and tourists and niche markets overseas	1. Import substitution by locally produced coconut products. 2. Introduce Good Agricultural Practices (GAP) certificate to ensure the quality of value-added products.	1. Introduce ISO, Geographical Indicators (GI) for each island and form a fair-trading community .	1. Awareness programs on certification and labelling for more benefits (premium) to farmers and processes	1. Improve capacity and import raw materials to add value and re-export.
10. Develop infrastructure facilities to enable efficient development of coconut sector	Construct an office and pest management laboratory.	1. Plan a building to house the Coconut Development Unit 2. Plan a laboratory to carry out pest management activities. 3. Construct screen houses for mass rearing of parasitoids.	1. Construct office and entomology laboratory. 2. Use screen houses for mass rearing of RSW parasitoids.	1. Use office for Coconut Development Unit activities. 2. Use laboratory for pest management activities.

			3. Develop storage facilities in the islands and Male for coconut /young coconut and value-added products along with other agricultural products.	

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SUMMARY OF PRINCIPAL ACTIVITIES AND PEOPLE MET

Mission 1

16.08.23 : Arrival in Male

17.08.23 : Meeting with the Officials of the Ministry of Fisheries, Marine Resources and Agriculture; Ms. Aminath Shafia, Permanent Secretary, Mr Hussain, Faisal Director, Ms. Shurufa Abdul Wahidh FAO, Maldives
Meeting with Stake holders, Mr. Adam Adeel Agro National Corporation, Mr. Masood Mohamed General Manager, Seagull, Ms. Hawwa Nafeela Manager, Admin Services, Seagull.

18.08. 2023 – 20.08.2023 : Visited L. Thundi, L. Baresdhoo, L. Fonadhoo and L. Maandhoo accompanied by Assistant Agricultural Officers, Mr Lahfaan and Mr. Yamin.
Met with Mr. Ahmed Moosa, Council Officer (L. Thundi), Mr Ibrahim Shaheen (Managing Director), Mr. Ali Waheed (Assistant Director) of L. Maandhoo Fisheries Complex, Mr. Azzem, Council Officer (L. Fonadhoo).

21.08.23 – 24.08.23 : Visited HDh. Hanimaadhoo, Ha. Kelaa, Ha. Maafahi, HDh. Finey, Sh. Goidhoo accompanied by Assistant Agricultural Officers, Mr Lahfaan and Ms. Shareefa Ali.
Visited Agriculture Center in Hanimaadhoo and met with Mr. Ali Waheed, Assistant Director and Ms. Shareefa Ali at the Center. Met with Council member in Kela. Met President (Mr. Adhaan), V. President (Mr. Jawaza Hussain) and staff of HDh. Met Finey Council. Met President and staff of Goidhoo Council.

25.08.23 – 26.08.23 : Visited Aa. Thoddoo accompanied by Khaleel (Asst. Agriculture Officer) and Mr Yamin. Met Mr. Ali Farish Senior Council Officer.

27.08.23 – 28.08.23 : Visited K. Kaashidhoo accompanied by Mr Yamin and Ms. Hadiya Mohamed (Asst. Agriculture Officer).
Met Mr Amir, President and members of Kashimaadhoo Council.

29.08.23 – 30.08.23: Visited ADh. Maamigili and ADh. Ariadhoo accompanied by Mr Lahfaan.
Met Mr. Imad Farooq, President and members of Alif dhal Council.

31.08.23 – 02.09.23 : Visited Gn. Fuvahmulah City accompanied by Mr Lahfaan and Ms. Sana (Asst. Agriculture Officer).

Met Mr. Ismail Rafeeq, Mayor and staff of Fuvahmulah City Council.

03-09.23 – 05.09.23: Visited S. Addu City (Hithadhaoo) and S. Addu City (Hulhumeedhoo) accompanied by Mr Lahfaan.

Visited area with Ms. Shizna Council member. Met Mr. Ali Anwar and staff Addu City (Hithadhaoo Council). Met Ms. Maanaa Council Executive of S. Addu City (Hulhumeedhoo) and Ms. Ashraf, Mr. Simad Shafeeg (NGO, Meedhoo).

06.09.23 : Meeting with Dr Hussain Rasheed Hassan, Minister of Fisheries, Marine Resources and Agriculture, Ms. Mariam Vishama Ahmed Director/ Animal Health and Veterinary Services Section, Mr. Ali Amir, Director/ Agriculture Training, Extension and Adaptive Research Section, Ms. Shurufa Abdul Wahidh and Mr. Lahfaan Moosa.

Mission 2

Biotic Stress Management Specialist

31.10.23 : Arrival in Male
01.11.23 : Arrival in Hanimaadhoo with Mr Yaamin, Assistant Agriculture Officer. Met with Mr. Ali Waheed, Director of Hanimaadhoo Agriculture Center and Ms. Shareefa Ali (Assistant Agriculture Officer).
02.11.23 : Visited Kella with Mr Yaamin and Mr. Adrashid (Assistant Agriculture Officer).
03.11.23 : At Hanimaadhoo Agriculture Center
04.11.23 : Visited Maafahi with Mr. Yaamin, Ms. Shareefa Ali and Mr. Alrashid.
05.11.23 : At Hanimaadhoo Agriculture Center
06.11.23 : Return to Male

Agronomist and Value and Supply Chain Specialist
06.11.23 : Arrival in Male
08.11.23 : Attended final workshop (all 3 Specialists)
09.11.23 : Leave Male (all 3 Specialists)

ACKNOWLEDGEMENTS

We are thankful to the FAO for assigning us this mission and particularly, Mr Vimlendra Sharan, FAO Representative for Sri Lanka and Maldives, Mr. Nalin Munasinghe, Assistant FAO Representative (Programme) and staff of FAO, Sri Lanka for their guidance and assistance. I thank Ms. Shurufa Abdul Wahidh, FAO-Maldives for her untiring support and guidance for the visits and throughout our stays in Maldives.

We thank the Government of Maldives and the Ministry of Fisheries, Marine Resources and Agriculture for their acceptance and facilitating our visit and excellent arrangements made for a successful mission. I am indebted to Mr. Lahfaan Moosa and Mr. Mohamed Yaameen of the Ministry for coordinating the visits and assisting in every aspect during our visit and other Ministry officials accompanied us in the visits. Staff at the Hanimaadhoo Agriculture Center provided necessary facilities in setting up insect cultures.

We had fruitful discussions with the members of the Councils and farmers/processors and our sincere acknowledgement goes to them too. Their kind hospitality and assistance in the visits are greatly acknowledged.

Director of the Coconut Research Institute permitted the Biotic Stress Specialist to use the laboratory facilities to which we are grateful. The support and expert assistance given by the staff officers, Ms. Harshani Dilrukshika, Ms. Pavithra Silva and Ms. Dilky Kulasinghe of the Coconut Research Institute in identification of the insect specimens are greatly acknowledged.

Annex 1

STATUS OF COCONUT CULTIVATION, PEST INFESTATIONS AND VALUE CHAIN ACTIVITIES IN DIFFERENT ISLANDS OF MALDIVES

L. Gan

L. Gan was visited on 18 August 2023.

Coconut holdings managed by the Mukurumuga Council was inspected. It was observed that coconut is growing in wild in an unorganized manner with other types of trees and shrubs, except a part of the coconut holding which was clear of undergrowth. High density of palms has resulted in overlapping of coconut fronds preventing sunlight from falling on leaves. The undesirable situation of the holding brings about empty crowns without nuts. The production of inflorescences and nut setting of these palms were adversely affected by the prevailing stress conditions.

Traditional Maldivian varieties of coconut with large numbers of very small nuts were observed in different areas. This variety is not suitable for commercial cultivation. Highly bearing tall palms were also found in areas where palms are planted at a reasonable distance. This island has desirable soil condition and shallow water table, which is ideal for profitable coconut cultivation. Heavily bearing tall and dwarf palms were observed in home gardens.

To assess the pest and disease situation several areas with coconut was inspected and close observation of plams were made in 5 locations. Whiefly damage was not present in all locations confirming that L. Gan is currently free from whitefly infestation. Both hispid beetle and *Oryctes* beetle damages were low. Due to high rat population, considerable number of immature fallen nuts were observed. The messy and polluted ground situation and overcasting of coconut canopy has led to high population of rats.

Coconuts grown in the island are used for culinary purposes and no value addition is being carried out currently.

L. Baresdhoo

L. Baresdhoo was visited on 18 August 2023.

The entire island is comprised of one coconut plantation, which is managed by the Government owned company, AgroNat and Maldivian Integrated Tourism Development Corporation (MITDC). This uninhabited island of about 73 ha was originally started about 35 - 40 years ago with planting material imported from Malaysia. The size of the mature nut is large, and the husked nut weight is also high compared to other types of coconut. The plantation was established correctly at 25' x 25' square planting system which is acceptable for commercial cultivations. However, due to some reason, the entire plantation has not been properly managed for many years resulting in heavy growth of shrubs, trees and weeds in between coconut avenues preventing the collection of fallen nuts. Coconuts in the plantation are not harvested, but fallen nuts are collected. As a result, large number of fallen nuts have germinated on the ground and grown to different heights, forming a thick jungle like undergrowth. Due to the large trees within the thick undercover vegetation in coconut avenues, the plantation is inaccessible.

Due to prolonged negligence in the plantation management, all palms are subjected to very high competition with coconut seedlings and other deep-rooted trees and shrubs resulting in low nut yield. Almost all mature palms show acute deficiency symptoms of major plant nutrients (Nitrogen, Potassium, Phosphorus and Magnesium) leading to yellowing of coconut fronds with scorching of leaf tips. Palms were not fertilized either with organic or chemical fertilizer for many years. It was clearly observed that palms located in the deep jungle areas are declining rapidly in terms of growth and nut yield. However, palms located in cleared areas are bearing heavily with many nuts in bunches. This observation clearly shows the natural potential of this plantation for easy rehabilitation. It was difficult to realize why such a protentional plantation has been neglected so badly by allowing deterioration of valuable resources.

No records were available regarding palm census, nut yield, income and expenditure. It was very hardened to note burning of dried coconut fronds and other plant materials, collected either side of the roads for easy clearing of jungle areas. This practice is causing severe fire damage to healthy coconut palms. Stems of these palms showed bleeding symptoms, which could lead to secondary pest and disease attacks and even death of palms. Setting fire in this manner should be avoided.

In the plantation, a coconut nursery is maintained with germinated nuts collected from the plantation. The naturally germinated seedlings are uprooted to establish the nursery. It was observed that the quality of seedlings raised in the nursery in this manner was highly unsatisfactory, therefore these seedlings should not be issued for planting programs. However, properly maintained coconut nursery

could be established in the plantation with seed nuts collected from selected mother palms within the existing palm population. Necessary technical guidelines should be followed in selecting mother palms and the establishment of coconut nursery. The selection procedures of seedlings at the nursery also be followed before issuing for field planting.

The overall nut production, productivity, land utilization efficiency and the profitability of this plantation is highly inadequate due to prolonged negligence. No basic agronomic requirements of cultivation and land management have been fulfilled for many years. The staff at the estate, has no basic understanding about the agronomic and technological requirements for profitable coconut cultivation, hence a huge technology gap exists. However, with proper technology-based planning, investment and implementation, the entire plantation could be rehabilitated within a two-to-three-year period. This is one of the short-term high priority areas in the revitalization of the coconut sector.

There is no whitefly damage observed in the plantation. However, hispid beetle damage is at a moderate level, but *Oryctes* beetle damage was low. Few palms were seen dead due to lightening damage.

L. Maandhoo

Maandhoo was visited on 19 August 2023.

The coconut plantation in Maandhoo is owned and managed by the Horizon Fisheries Company. The plantation comprises of two blocks, one is 70 ha in extent and located across the main road and the other is in the Fisheries factory premises which is about 15 ha.

Part of the 75-ha block is being cleaned by removing shrubs and trees which is the first step of the plantation rehabilitation plan. A very large extent of this block has been neglected for years resulting in a thick coconut jungle with other trees. The bearing plantation is between 45 -50 years of age, planted with 24' x 24' square planting system with a coconut variety imported from Malaysia. Fallen nuts are collected, de-husked and transported to Male. Heavy growth of unwanted wild trees, shrubs and thick growth of weeds found in coconut avenues prevents collection of fallen nuts. The income generation of this plantation is currently inadequate. These palms have not been fertilized for many years and no picking of coconut is carried out.

The 15-hectare coconut block at the factory site is maintained well by applying coconut fertilizer imported from India. The nut production is very much higher compared to the neglected block. Fish meal is being applied to coconut as an organic fertilizer, which has given positive results in terms of nut yield. Although goat manure is available on site, it is not being used as an organic manure for coconut. The company management is highly interested in the rehabilitation of both blocks. They also prefer to have a coconut nursery with nuts obtained from selected mother palms. But they do not have required technical knowledge for mother palm and seed nut selection procedures and nursery techniques.

No whitefly damage was seen in the plantation. But it was observed that 1-2 leaves of few coconut seedlings in the block across the road was slightly infested with live colonies of whitefly. Hispid beetle damage is at a moderate level, but *Oryctes* beetle damage was low.

The company has a high potential and capacity for value addition of coconuts and willing to do so and help coconut farmers as a part of the corporate social responsibility of the company. They are already producing many value-added canned fish products and one of them is with desiccated coconut.

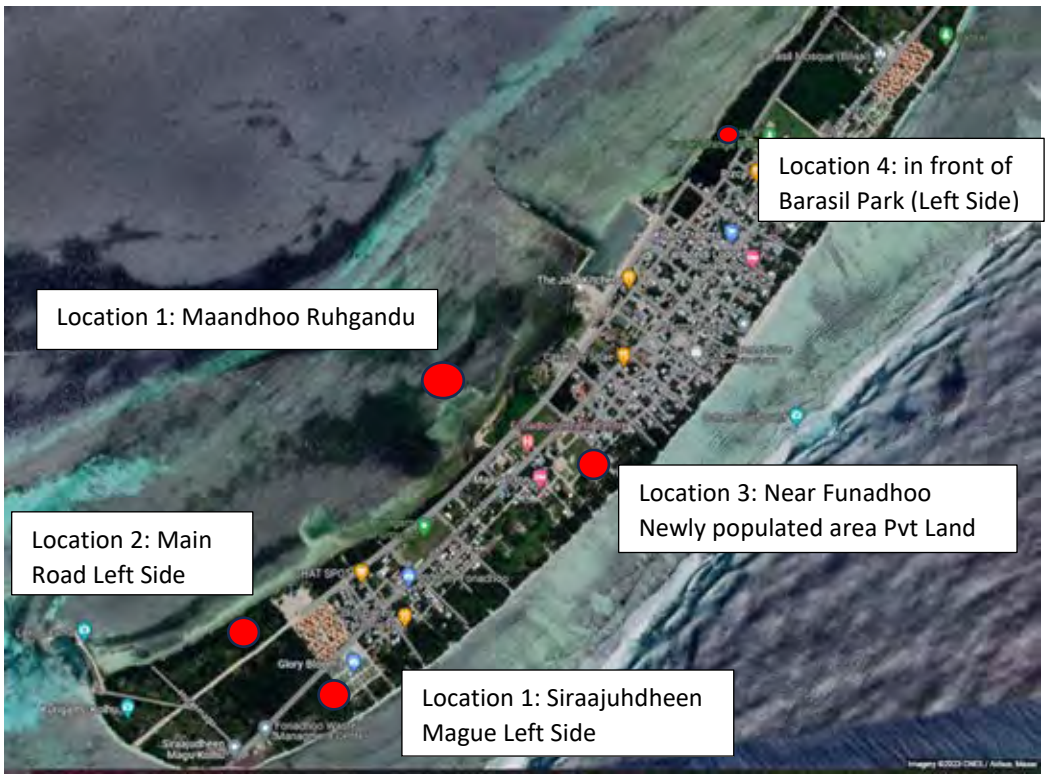
L. Fonadhoo

L. Fonadhoo was visited on 19 August 2023.

Whitefly infestation was not widely observed in Fonadhoo. Four locations were selected to represent the coconut growing area for close observation and sampling. In these locations young palms were examined for presence of whitefly infestation as no whitefly damage was observed in the area. In locations 1 and 2, no whitefly infestation was observed. Initial infestation was present in locations 3 and 4. Live whitefly colonies were found on few young palms of about 7 years old planted along the roadside having adult whiteflies, eggs and immature stages. RSW and BNW were present.

Whitefly damage has not been reported before from L. Fonadhoo.

Hispid beetle damage is at a moderate level, but *Oryctes* beetle damage was low.



Sampling locations in L. Fonadhoo

HDh. Hanimaadhoo

The visit to Hanimaadhoo was made on 21 August 2023.

The Agriculture Center under the Ministry is situated in Hanimaadhoo, in which research and extension activities in agriculture are being carried out.

In this island most coconut lands are owned by the Council but neglected for years. They are growing in wild and heavy undergrowth of coconut seedlings and other plants were seen. Due to high competition and shading these coconut plants are not achieving the potential yield. Inhabitants are provided with a block of land for house construction, where they can plant at least few coconut palms for their own use, if necessary. The residents are allowed to collect fallen coconuts from Council owned coconut lands, free of charge, for their own use. There was no statistics available regarding the number of farmlands or coconut holdings in Hanimaadhoo. It was said that about 40 -50 years ago, coconut was well maintained, and nuts were picked by climbing. Copra processing too has been carried out for export.

Immature coconuts are in high demand and expensive. They are harvested by climbing palms or using ladders. Farmers have very poor technical knowledge regarding correct distance of field planting of coconut and managing them until bearing with appropriate agronomic practices. Educational or technology dissemination programs are not carried out either by the council or the center.

At the Agriculture Center, poly bagged coconut seedlings imported from Kerala, India was maintained to be distributed to other islands for their planting programs. According to the Assistant Agriculture Officer of the center, these seedlings have been physically checked for pests and diseases as a post quarantine measure. Discussions revealed that Maldives lacks post quarantine facilities to accommodate large amounts of imported plant material, which is a serious issue to be addressed considering the risk of invasion of serious pests from other countries.

Whitefly infestation has been there in Hanimaadhoo in the past 2 years. The damage varies in different parts of the island with severe damage in palms around the Agriculture Center. Throughout the island the whitefly infestation is presently subsided. But re-infestation was seen in many areas. Four locations representing the coconut growing area of the island was selected for sampling.

In the palms, in the vicinity of the Agriculture Center, up to half of the leaf canopy was damaged by whitefly and sooty mould. However, the previous infestation has now subsided and whitefly colonies in the lower leaves are absent. In the leaves of the middle canopy new infestation has started. It was

informed that the infested palms have been sprayed with 3% neem oil solution 03 months back and control has been achieved.

Location 1 - Leaf samples collected from this location revealed many new live colonies developing with large number of whitefly adults and immature stages. Similarly, many pupae with parasitoid emergence holes were noticed. The preserved specimens had parasitized pupae indicating that active parasitism is present. The puparia identified from this location confirmed as the whitefly species is *A. rugioperculatus*.

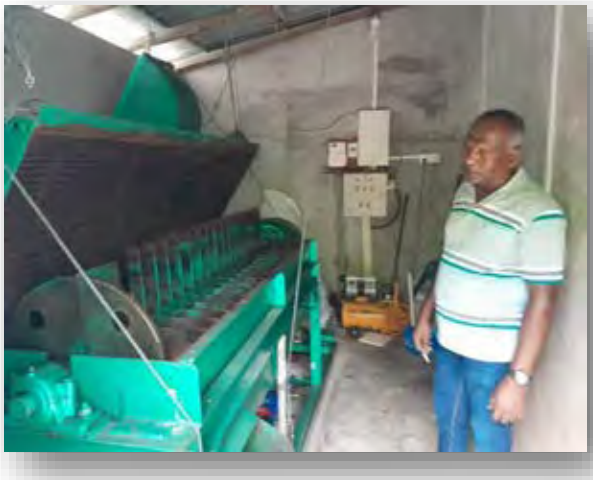
Location 2 – The whitefly damage was seen at a moderate level in the palms around 10 years of age. The colonies of the old infestation were washed off and absent. But re-infestation has started slightly with colonies having large number of adults and immature stages. Parasitized pupa was observed, and the preserved specimens of pupae had developing parasitoids. Both RSW and BNW were found.

Locations 3 and 4 – The whitefly damage and sooty mould was at a moderate level. There were no live whitefly colonies observed. Small numbers of coconut scale insects were noticed in some palms.

Sampling locations in HDh. Hanimaadhoo

In the second visit whitefly re-infestation was found in trees around the Agriculture Center. Samples collected from the palms revealed presence of both RSW and BNW. However, it was noted that the parasitism levels are also very high and nearly 60%.

One coir peat manufacturing facility is in operation. This is the only facility processing coir peat and mixed fiber for agricultural purposes in the island. The husk required for the process is collected from the jungle area. The capacity of the machinery is 100 husks per hour. The owner is willing to undertake production of coconut oil if the council gives assistance to import machinery and technology is available.



Coir peat processing unit

Ha. Kelaa

Ha. Kella was visited on 22 August 2023.

The island is also known as a mangrove edge of Maldives because of its large mangrove and jungle areas with pools of brackish water. The total land area is 230 ha. The number of households is about 250. About 10,000 coconut palms in different age categories are grown in the island, out of which about 5000 palms are under council management and others are owned by farmers. Lands of the island have been allocated to residents for housing and agriculture. The ownership of lands is with the council which is renewed in 1–2-year periods. They are allowed to cultivate any crop including coconut in their householdings. But now coconuts are not cultivated in housing blocks as it takes at least 3 - 4 years to bear nuts. If anyone wants to grow coconut on council land, he/she should register the tree with the council and pick the coconuts.

Residents are allowed to collect fallen coconuts from areas managed by the council, on a particular day of the week. The council has planned to replace the existing old palms with new seedlings in a 10 ha. block by entrusting the task to a registered company. The council members and growers have very poor technical knowledge on coconut cultivation and management of plantations. Badly neglected coconut blocks for years have resulted in a jungle type situation where palms are showing acute deficiencies in major plant nutrients combined with empty crowns, yellowing and scorching fronds. Palms in large areas are highly unproductive due to overcrowding, competition for nutrients with other trees and young palms. Because of the land ownership issue people are reluctant to plant coconut in their holdings because of its perennial nature.

The damage due to whitefly infestation is severe with about half of the leaves of the canopy was infested in many palms. Currently, the infestation has been subsided and the old colonies of whitefly are absent. The newly emerging re-infestation is also mostly dead. It was said that whitefly infestation has affected the income generated from coconut leaf weaving and exporting as they could not find undamaged leaves. Coconut leaf samples were taken from 3 locations representing the coconut growing area of the island.

Location 1- There were no live adults and live immature stages found. Only very few live puparia and parasitized pupae were observed and collected for laboratory analysis. It was revealed the species is *A. rugioperculatus*. Also, laboratory analysis showed presence of developing parasitoids in puparia.
Locations 2 and 3 – No live whitefly colonies were observed.

Sampling locations in Ha. Kella

In Kelaa, hispid beetle damage is at a moderate to severe level, but *Oryctes* beetle damage was low. Rat damage was observed in many neglected plantations due to poor sanitation conditions.

It was understood that in Kella fresh coconut consumption by a five-member family is 2 nuts per day. Also. they use 50 young coconuts (Kurumba) per day. The excess mature and young coconuts are exported to Male. Currently, there are 5 - 6 coconut and young coconut collectors in the island. Production of masala is being carried out as a cottage industry using 30 nuts per day. Today tapping is carried out by one person who has been in this operation for the last 25 years. He taps 6 trees and collect 5-6 liters of toddy, which is packed in cool boxes and sold.

In the second visit to Kelaa it was found that some palms that had whitefly infestation before are reinfested, but there was very high parasitism in all sites the samples were collected. The parasitism level was over 50%.

Ha. Maafahi

Ha. Maafahi was visited on 22 August 2023.

At Maafahi agricultural projects are carried out by the Seagull Group. The coconut plantation, vegetable and fruit cultivations and animal projects are carried out by the Maafahi Agri and Fisheries Project. The island is leased out to this project by the Government for agriculture and protection of environment on a renewable contract. The island is mainly planted with around 10,000 coconut palms of 15 - 70 years of age. Coconut is the major cultivation there producing both young and mature coconut. All products are transported to Male by boat every week. In addition to coconut, banana, papaya, vegetables and green house crops are also cultivated in large scale. A large heard of goats are also maintained with stall feeding and free grazing systems. Goat manure collected from this farm is used for the compost making project carried out in the plantation.

Drip irrigation facilities are available for green house cultivations. Large rainwater collection tanks are installed to supply water for irrigation systems. Wide variety coconuts are cultivated and considerably managed. Majority of bearing palms are of tall types. Dwarf and hybrid varieties imported from other countries have been planted on either side of internal roads Traditional Maldivian coconut variety with a large number of very small nuts were also observed in different blocks. Bearing mature coconut blocks are highly crowded due to close planting at 20' or less resulting in low nut production. In some blocks palms were seen in rows but at close distance. The nut production of these blocks was very low due to overcrowding and overshading. Fallen nuts are collected, husked and transported to Male. Nearly 2000 to 2500 mature husked nuts are transported to Male weekly. Young coconuts are harvested weekly from dwarf varieties of different color forms by using tall ladders. Nearly 1500 young nuts are transported to Male weekly.

Although large heaps of compost are produced in the plantation by using crushed coconut fronds, and other plant materials from banana and other fruit plantations enriching with goat manure, it is not applied to coconut, but use for fruit plantations. About two years ago, fertilizer application with Urea, MOP and granule mixtures has been carried out in coconut. Tractors and other heavy machinery are used for weeding, cleaning, crushing, planting, levelling, compost making and other field operations.

In general, the plantation is mostly well managed and maintained, however improvements are necessary to achieve maximum potential.

Whitefly damage is extensively observed at moderate – severe level with heavy sooty mould attack. According to the Manager of the estate coconut production has dropped by about 1/3 due to the

infestation. It was observed that the previous infestation is subsided, but reinfestation is commencing in lower and middle whorl of leaves. It was also noticed that palms on the roadside and open spaces are more damaged, and the damage is severe in king coconut palms and yellow/ orange hybrids. Some infested palms have been sprayed with neem oil mixture which has given control; however, reinfestation has occurred about 3 months after spraying. Samples were collected from 3 locations (Fig. 20) in the plantation and checked for stages of whitefly.

Location 1- Sample was collected from an infested young king coconut tree on the roadside. Many egg spirals, immature stages and adults were observed. Also, puparia with parasitoid emergence holes were recorded.

Location 2 – Samples were collected from a green hybrid palm. Few live whitefly colonies and parasitoid emerged puparia were observed. The old colonies have been washed off leaving only the damage symptoms.

Location 3 – No white colonies were observed.

In both locations RSW and BNW were observed.

Sampling locations in Ha. Maafahi

Rat damage to young coconuts was observed to be very high, even with trunk banding with metal sheets. Rat trapping cages are extensively used all over the plantation to minimize the damage. Overlapping

of fronds enable rat movement from one palm to another and breeding of rats in the surrounding forest area will be an eternal issue in managing the rat population.

At Maafahi, hispid beetle damage was observed at moderate to severe level. However, *Oryctes* beetle damage is low.

In the second visit to the island, it was observed that whitefly is reinfesting the palms, mostly the same palms that have been previously infested. Live whiteflies of both species were observed. Parasitism levels are increasing.

HDh. Finey

HDh Finey was visited on 22 and 23 August 2023.

Finey has a land area of 119 ha. and coconut is found in all parts of the island. The total population is about 607, but only about 350 are currently residing in the island. Residents have enough coconut for their consumption. The level of technical knowledge on coconut cultivation and management of lands was found to be very poor among the council officials and farmers.

Coconut palms in the council owned lands are leased out to community-based cultivations. Some other blocks of lands are issued to people for housing and cultivation. They cultivate fruits, vegetables, melon, papaya, banana in large extents. The existing coconut holdings in the island are highly overcrowded leading to many empty crowns without nuts. New coconut planting programs are under way with dwarf varieties imported from India, as demonstrative cultivations. Overcrowded mature palms have shown severe nutrient deficiency symptoms with yellowish fronds and lesser number of bunches.

Planting distance followed by the council is about 20 feet, even in new plantations, which is highly inadequate for profitable coconut cultivation. The council maintains a large area of coconut which was originally established over 70 -80 years ago. These lands are neglected for years resulting in coconut jungles with seedlings germinated from fallen nuts. The empty funnel shaped coconut crowns clearly shows that palms are not receiving enough sunlight. Large area of the island is maintained as a mangrove conservation area. The council has a program to lease out 100 palms belong to them by bidding. The council also has a plan to import Malaysian dwarf seedlings and issue to growers for household planting. These seedlings could be planted and maintained as demonstrations with correct technologies.

According to the Council officers, the whitefly infestation has been severe and even understorey plants have got infested. The observations too revealed that whitefly damage is severe with nearly half of the leaf canopy affected and sooty mould was present. Currently, the infestation has subsided, and those colonies have been dislodged leaving only the damage symptoms. The Ministry have distributed a commercial product of *Beauveria bassiana* fungus preparation imported from India for spraying on whitefly infested palms. Leaf samples were collected from 3 locations to represent the coconut growing area of the island. Re-infestation was seen in some locations, but still the population of whitefly is low.

Location 1 – Many whitefly adults and live stages of immatures were observed in samples. Parasitoid emerged puparia were seen.
Location 2 – No live colonies of whitefly were observed in samples.

Location 3 – Live colonies of white flies with adults and immature stages were noticed in samples. Parasitoid emerged puparia were seen.

Laboratory analysis confirmed presence of RSW and BNW in all locations.

Sampling locations in HDh. Finey

Hispid beetle damage was observed at a moderate level. However, *Oryctes* beetle damage is low.

It was noted that the island produces sufficient coconut for their consumption and excess is exported to Male. Both mature and tender nuts are exported. The households manufacture Masala as a cottage industry and sell to Male at a price of a Rf. 150/- per 700ml bottle. Masala has a high demand within the island and Male. They send their products such as coconut, young coconut, watermelon, pumpkin, bitter gourd, sweet potatoes, and bred fruits to Male via Kulhudhuffushi (transit port) port.

Weaved cadjan leaves

Extraction of Ekal

Sh. Goidhoo

Sh. Goidhoo was visited on 23 and 24 August 2023.

Sh. Goidhoo has a total extent of about 98 ha and 30% of it has been allocated for housing. Only a small area is under coconut The council members are highly interested in scientific cultivation of coconut in the island. Under the prevailing organizational structure of the council there is no responsible officer assigned to assist coconut development activities and needs of growers. Technical knowledge of members and officials on coconut is very poor, but they are interested in rehabilitating the coconut sector in the island. The proposed land use map presented by them have no priority given for development activities in the coconut sector. Ten hectares of land are allocated for agriculture including coconut. It was observed that coconut lands are badly neglected and allowed to grown wild for many areas.

The damage due to whitefly infestation was severe in Goidhoo, but currently the infestation is largely subsided. However, re-infestation was observed. In addition to coconut, a severe infestation of whitefly was observed on leaves of *Ficus* plant growing near the beach. It was informed that inhabitants have cut down some infested coconut trees as the whiteflies move inside their households, infest other fruit plants and growing of sooty mould on their cultivated plants and ornamentals. It was also found out that whitefly infestations have occurred time to time in the past, but never in this severity. Leaf samples were collected from 03 locations representing the area under coconut.

Location 1 – Infested leaflets were collected from young coconut palms of age 10 years growing on the roadside. Live whitefly adults, eggs and immature stages were observed. Parasitoid emergence holes on some puparia were noticed.
Location 2 – Samples were collected from adult palms on the roadside. Live whiteflies and large number of eggs were seen. Live coconut scale insects were also observed near whitefly colonies.
Location 3 – Samples were collected from adult palms at the edge of the forest area. No live colonies of whiteflies were found.

Morphological analysis revealed presence of RSW and BNW in all samples.

A few value-added products; masala production, weaving of coconut leaves for roofing and manufacturing coir rope are done at household level. One person can weave 4 sheets of 4’ length mats per day. For coir rope production residents collect husks from the jungle free of charge and soak them in the sea or in a barrel for 3 months. After beating and separating coir, it is used for making rope.

Sampling locations in Sh. Goidhoo

Rope manufacturing

Coconut Sweets

Aa. Thoddoo

Thoddoo was visited on 25 August 2023. Thoddoo island has an extent of 157 ha. in which around 1500 coconut trees are growing. About 75 ha. of council owned lands are allocated for housing and the remaining lands are allocated for agricultural purpose. A larger extent of land is under vegetable cultivation. All agricultural lands have been given to people on five-year contract, so they are not interested to plant coconut due to its long-term nature. The island produces enough coconut for their own consumption and the excess mature and young nuts are exported to Male and other islands.

The soil, climatic conditions and ground water resources of the island are ideal for profitable coconut cultivation. Because of the highly favourable agronomic situation of the island, coconut plantations are very well established, and their production levels are satisfactory. Although coconut palms are doing well in these farming areas, farmers cut and remove coconut fronds to provide sunlight for other agricultural crops. The attention and priority given for profitable coconut cultivation are highly inadequate. The council members are interested to develop coconut, but the availability of suitable land is limited. Further they have no access to required technology, guidance and high-quality planting material. Fruits and vegetables are extensively cultivated in coconut growing areas with irrigation and fertilizer application which also has benefited coconut palms. Coconut palms found around farming areas are healthy and highly productive because of indirect benefits of systematic farming. Banana, papaya, chilies, leafy vegetables, betel leaf, and wide variety of crops are cultivated in the island. Farming in the island is mostly carried out by immigrant labourers. New coconut seedlings have been planted along the roads by school children and maintained by them with lot of care. These young palms are now in the flowering stage.

Traditional varieties of coconut with many small nuts are also used for new field planting, which should be avoided. The island has a very high potential for profitable coconut cultivation along with other crops as a coconut-based farming system. Different colour forms of dwarf coconuts are also found in the island which are used for drinking purpose. Betel leaves are extensively cultivated in the island with very tall support. The produce of the island is sold to tourists and balance is sent to Male.

An inspection of coconut trees revealed that whitefly damage or infestation is not present in Thoddoo. Coconut in the island is free from hispid beetle damage, some palms with mild *Oryctes* beetle damage was observed.

K. Kaashidhoo

Kaashidhoo was visited on 27 August 2023. This island is 276 ha. in extent and having 93 ha. under agricultural crops. It has a population of 2800 including migrant labourers. The main income of the residents is from agriculture and employment in holiday resorts. Lands have been distributed to about 400 householdings. In the past, council lands have been allocated for faming for a 2–3-year contact period, but now the council is proposing to extend the period up to 15 years. Because of the extended period, the interested parties could cultivate coconut in their allocated lands. At present there are about 830 cultivated farms.

This island also has ideal soil and climatic conditions for profitable coconut cultivation with correct management practices. There are coconut trees owned by the Council as well as farmers, mainly grown in the borders of farmland. In the other areas coconut is planted at close distance. There is one large coconut plantation which is considerably well maintained. Different tall types of coconut, dwarf types in different colour forms and imported seedlings from Malaysia and India are cultivated. However, the planting distance is highly inadequate leading to high density coconut clusters, where the productivity is less. Fairly large population of dwarf types have been cultivated along roads for harvesting immature nuts for export. Mature fallen nuts and immature nuts are sold to Male. Goat and chicken farming is also being carried out. It was observed that farmers sometimes burn dried fronds close to coconut palms, which damages the trunks of palms.

Inadequate knowledge in coconut cultivation is a serious issue in this island too. There is no system for the farmers to access to coconut cultivation and management technologies, training requirements and advisory support services.

Moderate to severe damage of whitefly with about half of the leaf canopy affected was seen in several areas. It was informed by the Council Officers that farmers have cut down some coconut trees due to whitefly damage. The Council has sprayed about 1000 affected trees with neem oil mixture once in 2019. It has controlled the infestation to an extent, but spraying all the coconut trees has been impossible. Households too spray their palms and other affected plants with soap water. In addition to coconut, whitefly has infested several vegetable and fruit trees, and farmers have even sprayed those with synthetic pesticides. Due to heavy pest infestation, it was said that people have lost their interest in coconut and palms are neglected. Some people have even removed coconut trees in their holdings which were heavily affected by whitefly. Now it has become difficult to convince them to plant coconut again in their holdings and their interest has shifted to cultivate vegetable and other fruit trees instead.

Leaf samples were collected from 5 locations representing all the coconut growing area of the island.

Location 1 – This is Mumthaz Farm having a mixed cultivation of banana, papaya and coconut. Nearly half of the coconut leaves of trees are damaged by whitefly. Re-infestation has set in with large number of live colonies of adults, eggs, immatures and pupae. Puparia with emergence holes of parasitoids were observed.
Location 2 – Naimbe Farm is mainly grown with banana. The coconut trees are severely damaged with half of the coconut leaf canopy affected. Sooty mould was present. No live colonies of whitefly were found.
Location 3 – Nasir Farm is having coconut trees of 15 years of age with banana as the main crop. The coconut trees are severely damaged with half of the coconut canopy affected. Sooty mould was present. Live stages of whitefly were present. Puparia with emergence holes of parasitoids were observed. A small, black coccinellid beetle was observed on leaves with whitefly infestation. However, whether it is a predator of whitefly could be determined only by detailed observation.
Location 4 – Esmail Farm is a coconut monocrop plantation of 30 – 40 years of age. Moderate damage to coconut leaves by whitefly was observed. Re-infestation has set in, and small population of live adults and other stages of whitefly was found. Puparia with emergence holes of parasitoids were observed. A small, black coccinellid beetle was observed on leaves with whitefly infestation.
Location 5 – Whitefly infestation was low with few numbers of live colonies. Several coccinellid beetles were observed on infested leaflets.

Morphological identification of samples collected from Kaashidhoo confirmed the whitefly species as *A rugioperculatus and P. bondari*.

No hispid beetle damage was observed in Goidhoo, but *Oryctes* damage was in low levels.

Some coconut processing activities such as weaving Cadjan, toddy tapping, and coconut peat production are being carried out in small scale. For weaving, coconut leaves are collected from the council areas and spray with water before weaving. Generally, 4 sheets of 4 feet long Cadjan are stacked into one bundle for sale. One person, especially women weave 3 bundles per day. It was said that one bundle is sold at Rf. 255. There is one toddy tapper in the island and toddy is used to produce coconut treacle which is currently sold at Rf. 300/- per 500 ml. bottle.

There is one producer of coconut peat. The coconut husks are collected from the jungle areas and spray with water to season. He is using a machine imported from overseas and made modifications to suit the process. It is possible to produce 25 bags of 20 kg per day and sells at Rf. 50/- per bag. Coco peat is sold to the islanders and balance is exported to Male. If appropriate machinery is provided, the producer is willing to increase the capacity and do other value-added products such as coconut oil, sweets, etc.

The Value chain specialist met one collector of coconut. He collects coconut, husk and sends to Male as seasoned nuts (1200 per week) and immature nuts (1500 per week). Immature coconuts are used to manufacture sweets. Coconut shells are also collected from the island and supply to hotels for decoration work and barbequing. Although the wholesaler wishes to add value to coco peat, fiber, and coconut oil if the technology is provided, absence of a regular market and price fluctuations are issues he has identified. It is understood that coconut oil and virgin coconut oil because it has a high demand in Male.

Sampling locations in K. Kaashidhoo

Coconut cadjan sheets

ADh. Maamigili

Maamigili was visited on 30 August 2023. Maamigili has an extent of 185 ha., but 119 ha is occupied by the airport. Hence, only a small area is available for any cultivation. The registered population is 3200 but resident population with migrant labourers is 4500. There are 460 households.

The farmers and council members are in the view that coconut is very useful and productive. But they have no special program or support services to increase coconut cultivation in the island. As the availability of agricultural lands are limited, intensive cultivation of coconut combined with other agricultural crops is preferred. There is a plan to cultivate coconut dwarf types which can be used for young coconut production as it is in high demand at present. In the householdings few coconut palms could be cultivated to supply coconut for day-to-day requirements. Home garden coconut cultivation should be promoted with high yielding planting material.

In Maamigili, whitefly damage was not observed. However, 3 locations representing the coconut growing area of the island were examined for the presence of any infestation. Close examination too found no whitefly infestation. There was no hispid beetle damage was observed. *Oryctes* beetle damage was low.

It was noted that earlier residents used to produce coconut oil, rope, etc. But now they use imported coconut milk and vegetable oils, which are freely available in the island. Currently, cadjan weaving and toddy tapping are taking place. Young coconuts have a high demand within the island. Farmers grow banana, brinjal, chili, and papaya for export to Male and other islands. Many migrant labourers are working on agricultural lands and even lease land to grow vegetables.

ADh. Ariadhoo

Ariadhoo was visited on 29 August 2023. This is a monocrop coconut plantation of 40 - 50 years of age. Currently it is managed by the Ministry, but there is no caretaker to look after the plantation. This plantation has a long and successful history of coconut and the person who established the coconut plantation had followed correct technologies, planting distances and field management as a coconut based integrated farming system. The ruins of farm buildings, structures and irrigation systems and even green houses are still seen in the plantation. Due to some reason, the entire plantation was neglected for years, as a result, fallen nuts have germinated and grown wild forming a jungle condition with other trees and shrubs.

There was evidence that outsiders frequently visit the plantation for collecting fallen nuts. They also have cut and removed green coconut fronds out of the island. Acute plant nutrient deficiencies and root competition with other trees are the cause for yellowing of fronds and low nut yield in the plantation. The entire plantation can be rehabilitated within a short period with a scientifically planned intervention. With this rehabilitation approach, coconut-based integrated farming systems could be brought back, and the overall land productivity could be enhanced.

There was no significant pest or disease damages were observed in the plantation.

Gn. Fuvahmulah City

Fuvahmulah City was visited on 01 and 02 September 2023. This is a large island with an area of 5 sq. km. with a registered population of 13,000 but only 11,000 people are residing currently. Tourism, fishing and agriculture are the main income generation activities of the island. Coconut is also grown largely in the island and exported to other islands. In householdings a variety of dwarf and tall palms are cultivated, but at high densities. Immature nuts harvested from them are used for drinking purpose.

Although soil and climatic conditions are ideal for systematic coconut cultivation, people still cultivate coconut at high density, which has resulted in empty crowns with low nut yield. Leaves of tall and mature palms were showing yellowing due to acute deficiency of plant nutrients. The coconut seedlings issued to people for home gardening are planted along the boundaries at very close distance. The coconut barrier between sea and the main road is with coconut palms in high density and hardly any nuts were observed on them.

Council Members and residents are highly lacking in knowledge on coconut cultivation and management technologies, but they are interested to attend awareness programs. Large banana, papaya and other fruit plantations were found where coconut palms are cultivated on the boundaries of blocks. A marshy land in large extent is present in the island which could be brought under coconut cultivation with ridge and furrow system. The council is very much interested in coconut cultivation in the marshy land in large extent in a systematic and sustainable manner.

In this island white fly infestation is very low compared to other islands. Damage symptoms of whitefly in few young palms was seen, especially yellow-coloured varieties. Samples were collected from 4 locations, having only 1-2 lower leaves infested. A very mild infestation of whitefly was revealed.

Location 1 – This is a residential area and leaf samples were collected from young palms. The infestation was in the very early stage and mostly whitefly adults were observed. The species found on the leaf samples were identified as *A. rugioperculatus* and *P. bondari*.
Location 2 – Leaf samples were collected from 10-year-old palms. No live colonies of whitefly were present.
Location 3 – Live colonies of whitefly was not observed. The previous infestation has been wiped off.
Location 4 – No whitefly infestation was observed.
Hispid beetle damage was not observed, probably due to the release of parasitoids earlier in this island. *Oryctes* damage was low.

Sampling locations in Gn. Fuvahmulah City

Toddy tapping is carried out by one person on part time basis. He taps 6 young trees and produce coconut sugar paste (*karu hakuru*) for sale. It is sold at Rf. 250 per 500 ml. It was said that toddy tapping is more profitable than selling young or mature coconuts. Lack of skilled labour is an issue to expand this business. There is a timber processer making coconut rafters for housing. Coconut palms are bought from the council. Toddy trapping with dwarf palms could be expanded to produce coconut sugar and other valve added products.

Toddy tapping

Coconut sugar paste

Addu City (Hithadhaoo)

Hithadhaoo was visited on 03 September 2023.

Earlier, Hithadhaoo was an agricultural island with many coconut cultivations. However, at present, it has become a commercial city with large number of constructions and development activities going on.

In small holdings coconut is doing well, but attention given for its development is highly inadequate. Farmers and households require good training and education on the correct cultivation technologies. Coconut palms are planted at close distance. It was observed that palms planted at correct distance are doing very well in terms of nut production. As the living standard of these people are high, household coconut consumption of fresh coconut is in decline. For food preparation they use processed milk or cream and imported oils. As this island was a British colony, it has influenced heavily on the present lifestyle of people. Nuts produced in the island is sufficient for their domestic consumption. On the beach side, coconut trees are planted at close density to provide shade to local and foreign tourists. Vegetable and fruit cultivations are carried out by the migrant labourers. There is a high demand for young coconuts, which is sold at Rf. 10 and matured coconut at Rf. 3-5. Excess products are exported to Male and other islands.

Whitefly infestation has not been reported in Hithadhaoo. Inspection of the area and the close observation of the palms in 3 locations showed no signs of whitefly damage or infestation. But in one location 02 whitefly adults (Unidentified sp.1) was found on young coconut palms. There was no damage of hispid beetle and *Oryctes* beetle damage was in low – moderate level.

Addu City (Hulhumeedhoo)

Hulhumeedhoo was visited on 04 September 2023.

Total registered population of the island is 3740, but at present only 1100 people residing in the island. Coconut is mainly cultivated in households, having over 3000 palms. In households, coconut palms planted at close distance resulted in poor nut setting and low nut yield. Although coconut is considered important it has been difficult to convince the people to carry out coconut cultivation and management correctly. Some farmers have experienced increase in coconut yield with the application of fish meal as an organic manure. Although people are expecting more nuts, they do not have the knowledge and experience for it. In the earlier occasions, coconut seedlings have been imported from Malaysia.

Hulhumeedhoo exports about 8000 matured nuts and 8000 young coconuts per week to Male and other island resorts at prices of Rf. 5 and Rf. 2, respectively. Very few farmers are growing other crops due to restriction of soil quality. Fresh coconuts are extensively used for making Masala Roshi and other meals.

Whitefly infestation has been there 2 years back, but presently damage is not seen. Since whiteflies have infested vegetable plants in the farmer fields, they have sprayed them with soap water solution, but not on coconut palms.

S. Addu City (Meedhoo)

Meedhoo was visited on 04 September 2023.

Coconut is grown in a small scale. A UNDP funded NGO project assist growing coconut in the island. The NGO has distributed 2000 seedlings among the households and carryout field monitoring and evaluation of seedlings issued. Small holders are willing to cultivate coconut seedlings with the correct guidance in the boundaries of agricultural lands. In one plantation it was observed that growth of young palms is highly satisfactory, but due to wrong advice given two seedlings have been planted in each planting hole. One seedling has grown well while growth of other is suppressed.

Whitefly damage is not observed. However, in observations 01 BNW was found on a young palm near a Hibiscus plant.

This area has enough coconut for consumption and therefore surplus of young and matured coconuts, about 6000 nuts per month are exported to Male and other islands. About 70 years ago, they have

exported copra to Sri Lanka and made coconut rafters for construction. Since, Addu Atoll does not have as many resorts as other Atolls, demand for agricultural products is low. There is a small factory producing virgin coconut oil and soap to be sold to the resorts in the Maldives. Their main objective of this NGO project (IEM funded) is to enhance income of women in the island. The company envisaged expanding its operations. The raw materials are for the production is bought from the households and from the council lands. The operations at still at a basic level, but with necessary small-scale equipment. Their target market is resorts in the Maldives. Oil is sold in bulk to Male, where packaging, labelling, and distribution is done.

Virgin coconut oil and soap manufacturing

Annex 2

CHARACTERISTICS OF COCONUT PALM AND ITS REQUIREMENTS

Coconut palm

Coconut palm (*Cocos nucifera, L*) is naturally thriving very well in tropical, warm, humid climate and in sandy loamy soils. Naturally, coconut is mostly found along the coast in Maldivian islands. However, it will do equally well in inlands provided that basic conditions are adequate. The palms in the seacoast benefit from a humid climate which is less subject to wide fluctuation of temperature. They are also benefited by ample availability of moisture due to the continuous seepage of fresh water to the sea from high inland areas. Further, the constant movement of the sub-soil moisture near the coasts caused by the ebb and flow of the tide is also beneficial to the palm *(*Thampan, 1993*).*

Propagation of coconut through seeds

Coconut palms are propagated exclusively through seeds. Only fully mature nuts with shaking water could be used for germination. The coconut seed germinates slowly, taking up to 4 months before the shoot appears. During germination, the embryo found in one of the tree eyes of nut start growing out a shoot and roots (Fig. 1).

Figure 1. Germinating embryo of a nut

Immature shoot grows upward while roots grow down penetrating the husk of the nut. To provide food and nutrient for the growing shoot and roots, the single cotyledon (seed leaf) grows inside the seed cavity. In about 4 – 5 years after planting, the stem or trunk starts to form from the seedling.

Crown of the coconut palm

The crown of the coconut palm has a single growing point. It contributes to the development of stem, formation of fronds, flowers and nuts. In a mature coconut tree, fronds bear leaflets arranged on either side of the midrib. Coconut crown has about 30 - 35 fronds. The average length of a mature frond is about 4 m. having about 200 leaflets in 90 – 135 cm. in length. An emerged coconut frond would be functional for about 20 - 35 months on the crown, contributing to food production through a process called photosynthesis. The old fronds falling off successively, with a rate depending on plant vigour and the climate. A productive palm produces 12 -14 new leaves (fronds) per year. In mature and well-nourished palms, each frond bears an inflorescence on its axil. At a given time, about 12 fruit bunches bearing fruits at various stages of maturity and about 10 – 12 unopened spathes (inflorescences) occur in the crown. Fronds on the crown are located showing either left-handed spiral or right-handed spiral pattern. The spiral arrangement of fronds ensures receiving maximum amount of sunlight. The leaf spirality is visible from the leaf scars on the trunk (Liyanage, 1999*).*

Stem of coconut palm

A clear stem begins to grow from about five years after planting of seedlings. The rate of elongation of the stem is high at the beginning of the growth and slows down as the tree ages. Under favourable conditions, in the early stages, the trunk grows about 1.5' in a year. Under shady and overcrowded situation, the coconut trunk (stem) elongates faster and getting taller even at young age.

Flower (inflorescence) of coconut palm

Coconut flower is an inflorescence having both male and female flowers enclosed in a spathe (Fig. 2). The number of inflorescences produced corresponds to the number of fronds produced by the palm (12 - 14 fronds/palm/year). Many male flowers are borne on top of the spikelet and few female flowers are located at the base of spikelet.

The male phase (releasing pollen from male flowers) takes about 20 days to complete. The female phase (receptiveness of female flowers for pollination) lasts 3 - 5 days in tall varieties and 8 -15 days in dwarf varieties. A normal inflorescence may have 10 -50 female flowers. The natural pollination occurs either by wind or insects (bees). During the nut development process, as many as 50 - 70% female flowers abort and fall off and remaining flowers develop into mature nuts. Immature nuts fall due to moisture sensitivity during first two months (24%) and 40% in the second two-months. There will be about 12 bunches on the crown of a palm at different stages of development. From the opening of inflorescence, another 12month period is required up to the maturity of nuts (Mahindapala,1991).

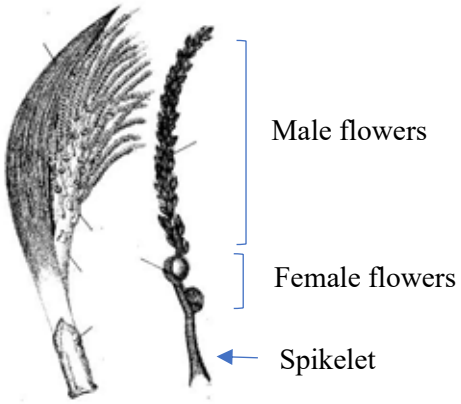


Figure 2. Parts of coconut

Coconut fruit (Nut)

Once natural pollination is completed, the fertilized female flowers take about 11 – 12 months to develop into mature nuts. When the nut is about 160 days old, it attains full size, and the kernel (meat) begins to form as a thin layer of jelly inside the endocarp or shell. Tender nuts are fully filled with water at about 220 days (7 months) is the ideal stage for drinking, as it attains the maximum sugar content (4.50g/100ml). The coconut embryo is found in one of the three eyes of the nut, and it remains dormant for about six weeks after picking (Fig. 3).

Figure 3. Cross section of a nut

The mature nut by weight is comprised of 35% husk, 12% shell, 28% kernel and 25% water. The coconut husk contains 30% fiber and 70% is coir pith. The coconut shell is marked by three depressions commonly known as “eyes,” one of which is soft, while other two are non-functional. The embryo which finally develops into a seedling lies just below the soft eye.

The fresh coconut kernel has about 35% oil, 4% protein, 10% carbohydrate. The main constituent of coconut is oil which accounts for 65 - 70% on dry weight basis. Coconut oil consists of about 90% saturated fat, rich in medium and short carbon chain fatty acids, which are considered as health friendly.

Roots of coconut palm

The roots of coconut palm arise from the enlarged basal part of the stem known as the "bole". There is no tap root or root hairs, instead numerous fibrous roots are produced horizontally from the "bole" (Fig. 4). The number of roots in a coconut palm depends on soil conditions and vigour, which ranges from 1500 – 8000. The absorption region of a root lies immediately behind the root cap (Fig. 5). When soil dries up cells in the absorbing region of the root develop thickened walls and cease to absorb water and uptake of nutrients causing a setback in the growth and production of palms. This explains why the recovery of palms after a drought spell is slow. Sometimes roots can grow much longer in sandy soils searching for water and nutrients. The greatest concentration of roots is found in the top 1 m. of soil depth and within a radius of 2 m. from the "bole" which is referred to as the manure circle of the palm. Coconut roots can tolerate salinity conditions and varying sea water levels.

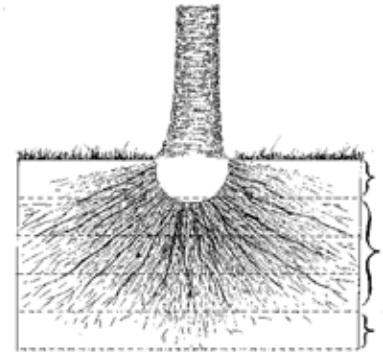


Figure. 4. Root distribution of a coconut palm

Figure 5. A live root showing absorbing region

Sandy soils found in most of the Maldivian islands has withered coral underlayer and a shallow ground water table. Due to frequent fluctuation of the ground water level, the highest concentration of roots is found close to the ground level (about 1.5 - 2 feet). As a result, surface sandy soils dry up quickly making surface roots inactive due to lack of soil moisture during dry periods.

Climatic requirements for coconut

The coconut palm is essentially a tropical crop and grown well in hot moist climate. For the vigorous growth and good nut yield, a mean annual temperate of 27 ^{0}C is ideal. The growth and production levels of coconut are affected in areas where the mean temperature fall below 21^0 C.

In Maldives, the temperate from March to April is between 32^0 C – 35^0 C in daytime, which may affect the pollination and the viability of pollen. This can seriously affect the nut setting thereby reducing the yield. It takes about 12 months from nut setting to mature a nut; hence effect of pollination can be seen only after a year.

Rainfall

Coconut cultivation aiming for higher nut production requires a total annual rainfall ranging from 1800 to 3000 mm, spreading uniformly throughout the year. The distribution of rainfall, soil drainage status and moisture holding capacity of the soil are found to be more important for nut production. As coconut is a continuously bearing palm, it requires well distributed rainfall throughout the year. Rainfall distribution is more important than the amount of total rainfall received over the year. Higher rainfall conditions can be advantages if the soil is well drained. But excessive rainfall has a negative influence on productivity as it is associated with loss of nutrients by leaching, waterlogging, low solar radiation, high relative humidity, cloudiness, and low evapotranspiration. During prolonged dry periods, the soil water levels, and ground water table drop to a low level having negative impact on the normal growth and the productivity of the coconut palm. In dry areas where the rainfall in less than 1000 mm, the economic production of coconut is possible only under irrigation. Rainfall has direct influence not only on the number of nuts produced but also the size and quality of nuts.

Maldives receives rains mainly in two monsoons in May – July and September – November in each year. During these periods, the islands receive sufficient rains. Periods in between two monsoons are dry months which may be prolonged due to delays in monsoonal rains. January to end April is a dry period with high heat stress. Maldives receive rainfall in Southwest and Northeast monsoons providing the average rainfall of 2090 mm.

Relative Humidity

Coconut palms thrive well in warm and humid climatic conditions. The ideal requirement of relative humidity is within 80 – 90 %. Very high relative humidity of over 90% throughout the year reduces transpiration which interferes with the moisture and nutrient uptake of the palm. It also encourages incidence of pests and diseases.

Soil requirements for coconut

Coconut performs best in well-drained, deep sandy loam soils (sandy loam soil consists of 30-40% clay, 25 -50%, silt and 25 -50% sand) (Fig. 6). The high content of organic matter enhances the water-holding

capacity of soil. The most favoured soil pH level for coconut is 5.5 to 7.5. Though the coconut is grown on a wide range of soil types, water supply is the single important factor that determines the suitability of soil type. In areas of heavy rainfall, well-drained soil types are the most ideal. On the other hand, in areas of poor rainfall or where long spells of dry periods are likely, it is always desirable to have deep and fine soil types possessing good water- holding capacity.

Figure 6. Surface rooting in sandy soil

Coconut growing soils in Maldives is consisted of weathered and un-weathered corral materials found underneath the ground and white sand. Coral rocks are the soil parent materials forming white sandy soils. Decaying coral particles in different sizes were observed within the soil profile. The water-holding capacity of the soil is very poor due to high porosity and infiltration rate. Coral deposits were found in deep layers. When the profile of soil is considered, clear layers of sediment soils cannot be identified. However, soil profile has no disturbance for root growth of coconut and other crops. The soil appeared poor in plant nutrients. From the colour of top and sub soils, it appears that the organic matter content of the soil is also very low. Hence the retention of soil nutrient in this soil is poor. It was also observed that the ground water level is shallow, and the water level fluctuates mainly within 3 - 5 feet level with high and low tides. As coconut roots could penetrate the soil easily and root system of coconut has established well, with the fully distributed root system, soil provides better anchorage even to tall coconut palms. When these soil characters are considered, this soil could be categorized as marginally to moderately suitable for coconut cultivation. Coconut roots could easily reach the ground water level and absorb required water. The hard conditions of ground water and high EC levels and 7.8 pH are within the tolerable levels for coconut. The hard condition of ground water may not be tolerable for some fruits and vegetables.

Varieties and forms of coconut

A variety in coconut generally refers to a single population having at least one specific morphological character which breeds true to type. The endemic coconut germplasm, according to the grouping carried out in Sri Lanka shows three distinct varieties viz. typica (tall), nana (dwarf) and aurantiaca (King

Coconut), based on morphological characters and breeding habits. Out of these, only tall variety is wildly cultivated at commercial scale, while dwarf variety is often used as a breeding material and natural beverage. The king coconut (aurantiaca) which is known to be endemic to Sri Lanka is grown mainly for beverage purpose. In coconut breeding programs, the dwarf green and dwarf yellow forms have been used as female parents in the production of Dwarf x Tall hybrids. These hybrids come into flowering at early stage of 3 – 4 years from planting and its annual nut yield is around 350 nuts per palm.

revealed that at present several coconut types are found in Maldives (Figs. 7 & 8). Typica tall coconut, which was originally planted over about 70 years are still found in many islands giving high nut yield (Fig. 7). This is one of the tall type suitable for commercial type cultivations. In addition, in some islands there are native tall coconut types with specific yielding characters and in different colour forms and nut sizes. The specific characters of native coconut are the presence of many female flowers in an inflorescence, large bunches with very small nuts in different sizes (Fig. 9). Most mature small nuts, have no economic value for consumption and value addition. Hence the native coconut type must not be used for commercial planting or rehabilitation programs.

It was observed that in large coconut plantations, which have been neglected badly at present, originally planted with seedlings imported from Malaysia, which is a tall type with a large nut size. In addition, king coconut, green dwarf, yellow dwarf, and red dwarf coconut types imported from other countries have also been cultivated successfully in home gardens and small plantations. Along these dwarf types, imported hybrid varieties have also been cultivated mainly to harvest immature nuts for the beverage purpose. All these palms are now in good health and are in well bearing stage. Mature nuts are not harvested and allow them to fall naturally. Fallen nuts are collected monthly and heap them for husking. Immature nuts from dwarf and hybrid palms are harvested and lowered with a rope. Portable ladders and climbers are used to pick immature bunches for sale.

Figure 7. Tall coconut type found in Maldives

Figure 8. Dwarf coconut type found in Maldives

Figure 9. Native coconut types with very small nuts

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Annex 3

RECOMMENDED AGRONOMIC PRACTICES IN THE REHABILITATION PACKAGE

1. Provision of high-quality planting material

It was revealed that most of the planting materials required for the ongoing planting activities are imported from other counties. For the implementation of sector rehabilitation activities, the provision of high-quality planting material must be given high priority. The selection of mother palms for collection of seed nuts is very useful in establishing high yielding and uniformly bearing coconut plantations.

Production of improved and hybrid planting materials with high genetic potential for higher nut yield requires long term measures such as the establishment of coconut seed gardens with hybridization programs. Until such time, the quickest and easiest scientific base for producing planting materials with high genetic potential is the selection of mother palms within the existing palm population. The general observation is that, in a coconut population established with unselected planting materials, about 80% of total nut yield is derived from nearly 20% percent of high yielding palms. Therefore, selection of mother palms and seed nuts is obviously a very useful practice in establishing high yielding and uniformly bearing coconut plantations.

1.1 Selection of mother palms

Mother palms should be selected according to the guidelines given below.

a. Identify high yielding coconut blocks within an existing plantation.

b. Select individual palms from identified high yielding blocks based on desirable agronomic features as below.

- Shout, sturdy and straight trunk and closely set leaf scars.
- Short leaves in a spherical orientation on the crown.
- The crown should comprise of 25-30 fully opened fronds with bunches of nuts at all stages of maturity.
- Short and stout petioles capable of providing a solid support to bunch.
- Short and strong bunch stalks.
- Bunches with medium sized nuts in sufficient numbers.

c. Monitor the nut yield and average weight of husked nuts in each pick for 3-5 years. Calculate the number of nuts per palm per year for each individual palm. Average husked nut weight is obtained by weighing three husked nuts selected at random in each pick.

d. Select the best palms, out of the initially selected pool, according to the following standards.

- The palm should yield more than 75 nuts / year.
- The average weight of a husked nut should be more than 700 g (average of 3 nuts)

e. Restrict the selection to the best 5 to 10 percent of palms in each block.

1.2 Selection of seed nuts

It is preferred that harvesting of nuts of the marked mother palms are done separately to avoid mixing of nuts in handling. After harvesting the selected palms, suitable mature seed nuts are selected. All immature and empty nuts should be rejected before delivery of seed nuts to the nursery. Small nuts and those with insufficient water, extra-large nuts that are difficult for laying and deformed nuts should also be rejected.

The selected seed should be laid in nursery beds immediately. If lying is delayed, they should be heaped and well covered with dry coconut fronds to minimize loss of nut water.

High yielding coconut block

A selected mother palm

1.3. Nursery Management

Planting coconut seed nuts directly in planting holes is not recommended. Properly selected, well grown, 7–10-month-old seedlings should be transplanted in the field to ensure fast growth and a uniform plantation. Seedlings may be raised either in nursery beds or in poly bags.

Selection of the nursery site

The land should be flat or with a low gradient. The soil should be sandy or sandy loam and well drained. The site should have sunlight, scattered shade, and a source of water in proximity (live shade is preferred for nurseries).

Nursery beds

Each bed should accommodate five rows of seed nuts and the length of the bed can be arranged as desired to facilitate routine activities. Seed beds should be about 15 - 25 cm above ground level and the distance between two rows should be 25 cm. The seed nuts are placed horizontally, with a spacing of 15 cm between two adjacent nuts in a trench, 10-15 cm deep, and covered with a thin layer of soil so that the surface of the nut is just visible. The seed nuts in any single trench should face the opposite direction. The seed nuts along a trench should also be placed in between two nuts of the adjacent row. Seed beds should be separated by shallow drains which join up to form a leader drain to remove the excess water during heavy rains. Normally coconut fronds are used as mulch to conserve soil moisture in the seed beds.

Coconut nursery bed with growing seedlings

Water supply

Regular watering is necessary during dry weather. Watering should commence if there is no rain continuously for 6 days and continued at 3-day intervals.

Weed management

Management of weeds in coconut nurseries is an important practice as weeds compete with coconut seedlings for soil moisture. Weeding should be carried out depending on the weather conditions, once or twice a month.

Non germinating seed nuts

These should be removed at the end of five months from laying. In a well-managed nursery at least 80% of seed nuts should have been germinated at this time.

Management of pests and diseases in nurseries

Termite damage - Termite or white ants cause considerable damage to coconut seed nuts and seedlings. They are usually attracted to the husk and eventually tunnel through the nut damaging the growing point. To prevent this damage, seed nuts should be dipped in a recommended insecticide solution prior to planting.

Collar rot - Collar rot disease is common in nursery seedlings with high soil moisture levels. The basal portion of the seedling starts decaying leading to bacterial infections. Collar Rot could be identified easily with the characteristic odour emitted from the rotten seed nut. Adequate drainage should be provided in nurseries where the water table is close to the surface.
Leaf die back - In certain instances, nursery seedlings show extensive die back of leaves. The die back starts from the tip of the leaf and circular brown patches could also be seen in the middle portion of the leaf. This could be easily controlled by spraying 1% copper fungicide.

Selection of seedlings

Seedling selection should be carried out with great care as a high-quality seedling will develop into a vigorous palm and bear early. All non –germinated nuts should be removed at five months from laying. A second selection is done after seven months from laying and at this stage all non-vigorous seedlings should be removed. In a well-managed nursery, the rejections should be kept at following levels. Non-germination - 8%, Late germination - 10%, Low quality seedlings- 12%. Accordingly, the total rejection at the nursery is 30%. Even at the good nursery management level, to obtained 100 selected seedlings, at least 130 seed nuts should be laid.

Seedling selection criteria

Vigorous seedlings have the following characteristics.

- Stout stem
- Dark green leaves
- Short petioles
- Early splitting of leaves

Seedlings are ready for field planting from the seventh month onwards.

A selected seedling suitable for field planting

Raising seedlings in poly bags

Selected seed nuts are kept in a pre-nursery vertically and apply water until they sprout. Then they are transferred to poly bags. The bags are made of UV radiation resistant black polythene sleeves of 200–500-gauge, 20/100 mm thick, and 40 x 28 cm with gussets measuring 15 cm. Several small punches should be made on the bag 1'' from the bottom to facilitate draining of excess water.

In a pre-nursery the distance between adjacent rows can be 15cm (6") and the nuts can be laid at 5 cm (2") distance in a row. In the pre-nursery, seed nuts are laid vertically in the beds. With the spacing recommended above, a nursery of one hectare in extent can raise about 50,000 seedlings (20,000 seedlings/ac). Seedlings are suitable for field planting after 8 months of poly bagging.

Coconut nursery with poly-bagged seedlings

Filling the bags with soil mixture

The soil mixture should have 3 parts of topsoil, 2 parts of cow dung and 1 part of coir dust.

Laying in poly bags - Germinated nuts from the pre-nursery are ready for poly bagging once the sprout attains 5 – 10 cm. If it produces long roots, they should be cut 1-2 cm from the husk. The bag is partly filled with the soil mixture and the sprouted nut is placed upright. The mixture is further added so that the upper surface of the nut is barely visible. It is advisable to leave about 3cm from the top to facilitate watering. Laying of nuts in poly bags can be done in weekly intervals for easy management.

Watering - Watering should be neither insufficient not excessive. About 2.5 liters/poly bag a day is recommended, preferably in the morning or late afternoon.

Spacing of bag - Spacing of bags obviously depend on the time the plant remains in the nursery and a triangular spacing of 75 cm X 75 cm X 75 cm is recommended if prolonged retention in the nursery *is* required.

Advantages of poly bagged seedlings are;

- Less root damage at transplanting.
- Plants establish sooner and are likely to flower earlier.
- Less field casualties and uniform plantations.
- Easy to apply fertilizer, control weeds and to irrigate at the nursery stage.
- Poly bagged seedlings could be kept for some time until weather conditions are suitable for field planting.

For further details regarding coconut nursery management and selection of seedlings, refer CRI Advisory Circular A 2 on Nursery management and seedling selection.

2. Field planting and management of young palms

Under the sector rehabilitation program, knowledge on field planting and management of young palms are required to carry out implementation activities under different conditions. Methods of planting coconut under different situations are discussed below.

2.1 New planting

The new planting refers to planting of coconut in an area where coconut is not cultivated previously. For new planting, the selected land is to be prepared by removing all disturbing trees and shrubs. It is advisable to level the land before marking the planting points. Depending on the types of coconut to be planted the planting system and the density must be decided. When tall types of coconuts are planted the most suitable planting system is the square plating system at 8 m x 8 m (26' x 26') where the number of palms is 158 per hectare (64 palms/ac).

New planting of coconut

Densities of square planting system

Spacing		No. of seedlings	
Distance (m)	Distance in (feet)	No of palms per ha	No of palms per ac
8.0 × 8.0	26 × 26	158	64

2.2 Replanting of coconut

In the replanting method, coconut seedlings are planted in an unproductive or aged coconut plantations after complete removal of old palms. If the removal of root bole is difficult, cut the stem at the surface level and cover it with soil sufficiently or apply coal tar on the cut surface to prevent the breeding of *Oryctes* beetle.

Planting coconut in between rows of old plantation

2.3 Under planting of coconut

In this planting system, seedlings are planted in between exiting rows of old palms, and the old plantation is gradually removed within 5 – 6-year period. Most growers prefer this system due to the advantage of obtaining nut yield from the remaining old palms.

When planting holes are marked, the new line should be based along the middle of the existing coconut square to minimize interactions of new planting with the old stand. Mark the planting point in the center of the old square. To make the system more successful, select the same distance of the old plantation for the new under plantation.

Remove all weak palms in the block at the initial state. The palms falling within a minimum distance of 8 feet from the newly marked planting points should also be removed (20% generally). After planting of seedlings, action must be taken to remove the remaining old stand gradually in stages based on the distance from the seedling to ensure adequate sunlight availability for growing seedlings. For further details regarding the planting densities, systems, and field planting of coconut seedlings, refer to CRI Advisory Circular No. A3 - Planting of coconut.

2.4 Planting systems for inter-cropping with coconut

The planting densities in Table - are more suitable for coconut-based farming systems, where wider avenues between coconut rows and closer distance within rows are kept. Depending on the type of intercrop broader avenues could be maintained proving more space for permanent agricultural crops. The suitable distance should be within 7.3 m × 9.6 m (24’ × 32’) - 7.3 m × 12m (24’ × 40’). The overall land productivity could be enhanced with the adoption of suitable farming systems.

Densities of coconut for permanent intercropping

Spacing		No. of seedlings	
Distance (m)	Distance (feet)	No of palms / ha	No of palms/ ac
7.3 × 9.6	24 × 32	149	61
7.3 × 12	24 × 40	140	57

Complete details regarding lining of planting points at the required distance and density are given in the CRI Advisory Circular No A 3 on Planting of coconut.

2.5 Planting coconut in urban households

In households, along with other agricultural crops, few coconut palms could be cultivated at least to fulfil the domestic coconut requirement. Hybrid coconut varieties, which will come into bearing in 3 years after planting are more suitable for this purpose. In planting coconut in households, basic agronomic requirements must be fulfilled. Depending on the availability of suitable lands in urban households this coconut planting program could be promoted under the sector rehabilitation activities. The program benefits urban population by fulfilling their domestic coconut requirements and provide revenue with immature nut harvest.

For further details regarding the planting coconut in home gardens, refer to CRI Advisory Circular No A 4 - Plant coconut in home gardens.

2.6 Planting coconut on roadsides

In most islands, large scale infrastructure development projects are underway including wide network of roads. Planting coconut on roadsides fulfil domestic coconut requirements as well as add an aesthetic value to the island. In Thoddoo a roadside coconut cultivation project is being carried out successfully by the council with the assistance of parents and school children in the area. This is an innovative approach and should be supported by providing high quality seedlings, preferably dwarf varieties. Such kind of activities could be promoted in other islands as a part of the sector rehabilitation project. This approach could also be used as a tool to motivate and change the attitude of people and students.

2.7 Planting coconut in waterlogging marshy lands

Coconut could also be cultivated successfully in water logging areas, with suitable land preparation practices by lifting the planting beds at least by 2 – 3 feet above the natural water level. Adequately wide ridges and deep furrows are used in other countries to cultivate dwarf and hybrid varieties for higher production of nuts. The large extent of a marshy land was observed in Fuvahmulah city council area. As no other crop can be cultivated under this condition, it is needed to have more time to assess its suitability for coconut cultivation with a massive ridge and furrow system. Hybrid coconut palms could be cultivated on wide ridges allowing water to collect and drain through the connected furrows. A sustainable integrated fish and duck farming system with coconut new planting could be introduced under the rehabilitation project. As the land preparation activities are highly expensive, a cost – benefit analysis must be carried out at first.

Marshy lands available for development in Fuvahmulah city

Marshy land planted with hybrid coconut in Thailand

2.8 Planting hybrid and dwarf coconut for toddy tapping

Cultivation of hybrid and dwarf coconut could be promoted in open areas, mainly for sweet toddy tapping. Same planting and management technologies could be practiced even for tapping palms. But the current methods of tapping and seasoning of inflorescences could be improved further by giving good training to tappers.

2.9 Planting coconut on the boarders of vegetable and fruit farms

In several islands, large blocks of land are allocated to people by the council to carry out farming. Some farmers have demarcated their farming blocks by planting coconut seedlings at very close distance. If proper coconut planting methods is introduced, they can have rows of dwarf coconut palms, which bear nuts early. Immature nuts in dwarf type are in high demand as a beverage and fetches high price. These palms will produce higher nut yield because of the side benefits they receive from fertilizer and irrigation for vegetable and fruits. This could be another short-term measure to be promoted in agricultural areas.

3. Planting coconut seedlings in the field

Unlike planting of annual field crops, field planting of coconut seedling must be carried out with utmost care as the palm will last for over 60 years in the same place producing nuts throughout. After the correct lining of planning points based on the required density, planting holes should be opened with a back-hoe machine. In sandy and loamy soils, the size of the planting hole should be 3’ x 3’ x 3’.

Field planting of coconut seedlings

3.1 Preparation of planting holes

For correct planting of coconut in the field, the following materials are required.

- Coconut husks - 25 husks
- About 10 -15 kg of cow dung or 8 kg of goad dung
- One kg of Young Palm Mixture (YPM) fertilizer
- Polly bagged or bear rooted selected coconut seedlings

Planting holes opened at the correct point, as per the planting system, must be prepared by adding 10 - 15 kg of organic manure, one kg of YPM fertilizer. The soil removed from the hole, is mixed well with organic materials and fertilizer then the soil mixture is used to fill the hole up to the ground level. The seedling is planted in the center of the filled hole in line with the row by completely covering the seed nut with the soil mixture. After planting the seedling in the hole, the surface area around the seedlings should be covered with coconut husks to conserve the soil moisture. If the soil is not wet, watering should be carried out after planting. The coconut husks are placed around the seedling, serves as a perfect mulch around the seedling. The mulch absorbs and retain water and create suitable environment for seedlings to grow fast.

When planting a Poly-bagged seedling, the planting hole should be prepared in the above manner, then the bottom of the poly-bagged seedling is carefully cut and removed. After that the bottomless ploy-bagged seedling is placed in the soil mixture, after removing soil to accommodate the bag in the soil then gently remove the polythene by lifting upward. The root system of the poly bag is not disturbed in this manner. Use the coconut husk mulch to conserve the moisture in the soil.

For complete details regarding the field planting of seedling and its management refer CRI Advisory Circular A 3- Planting of coconut.

4. Improving palm nutrition and soil fertility

Based on the findings of the census, the potential palms which can be rehabilitated are identified for the implementation of the package of technologies. The technology package includes enhancing plant nutrition and soil fertility too.

4.1 Improve the nutrition of palms

The growth and nut production status in most of the existing palms are poor due to inadequate plant nutrient levels in palms. Prolonged negligence of management has caused soil nutrient depletion resulting in palms with deficiency symptoms. To rehabilitate these palms, plant nutrient status of the soil must be improved with the application of a balance mixture fertilizer. The soil quality and organic content also be improved with the application of adequate quantity of organic manure.

Role of major plant nutrients in coconut

Coconut palm requires a regular supply of plant nutrients to sustain its growth and yield throughout its productive life. In a coconut plantation, considerable amount of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) are depleted from the soil, because of continuous removal of nuts and other parts of the palm. Out of the major nutrients required by the bearing palms, potassium has been found to be the most dominant followed by nitrogen, magnesium and phosphorus. Both nitrogen and phosphorus influence the production of female flowers while potassium is the most dominant nutrient responsible for improving nut setting and copra out turn. It is also believed that potassium regulates water economy of the palm by promoting the development of a larger root system and increasing water uptake. In addition to above macro nutrients coconut also requires micronutrients such as Copper, Zinc, Boron and Manganese. Among the major plant nutrients, a positive interaction between nitrogen and phosphorus could be observed. A negative interaction between potassium and magnesium could also be observed. It is important to maintain a proper balance between individual nutrients for their efficient uptake by the palm.

It has been shown that the nutrient requirement of young coconut palms (before flowering) is different from that of adult palms (bearing palms). As young palms are in their vegetative phase, they need more nitrogen and phosphorus for their growth, whereas adult palms require more of potassium than other nutrients for nut production.

Nutrient deficiencies in palms

Generally, deficiency symptoms occur in the palm unless nutrients removed by the palm are replenished by regular application of inorganic fertilizer and/or organic manure. Field investigations have revealed that most coconut soils are deficient in major plant nutrients and follow the priority order of nutrient for bearing palms was established K > Mg > N > P. It has been reported that widespread occurrence of potassium and magnesium deficiency in plantations particularly on light sandy and lateritic gravel soil is a limiting factor for maintaining optimum coconut production. In neglected plantations for years, soil and palm nutrient levels have degraded badly due to high root completion and non-application any fertilizer for many years. Generally, acute nutrient deficiencies produce characteristic visual symptoms on the foliage, but mild deficiencies can be diagnosed only by leaf analysis. Of the major nutrients, frequent occurrence of K and Mg deficiencies are observed in neglected coconut plantations. The N deficiency symptoms are observed occasionally but phosphate deficiency symptoms are not so common.

Palms with nutrient deficiency symptoms

For more details regarding the plant nutrient deficiencies, refer CRI Advisory Circular A7 on Nutrient deficiencies in Coconut palms.

4.2 Use of chemical fertilizer for coconut

The regular use of inorganic (chemical) fertilizer and/or organic manure will ensure continuous supply of macro and micro-nutrients required by the palm for its growth and nut production. Fertilizer use is one of the effective and convenient methods to increase coconut production in short-term. Generally, the effect of fertilizer application on the nut yield could be observed after about 2-3 years due to slow reproduction process within the palm. Young palms, if properly fertilized will commence bearing in less than 05 years after transplanting in the field and will take another one or two years to start producing regular crops. It is important that adequate fertilizer application of young palms during the pre-bearing stage has a strong influence in sustaining the vigorous growth and production of coconut in subsequent

years. Application of fertilizer is an essential input for achieving optimum growth and production. It is, therefore, not advisable to suspend fertilizer application purely even temporarily for economic reasons, as it would lead to further deterioration of the plantation. Under such conditions, fertilizer application at reduced rate is advocated. Although fertilizer is applied to the soil to satisfy the nutrient demand of the palm, a certain proportion of it is lost by leaching.

For further details regarding the types of coconut chemical fertilizers, different mixtures for both young and adult palms, application methods, time and frequency of application, refer, CRI Advisory circular A 5 Inorganic fertilizer application for coconut.

Method of fertilizer application for young palms

In the early stages of young palms (1-1½ years) chemical fertilizer or organic manure should be broadcasted up to about 1 ft. from the base of the palm and incorporated to a depth of 4 - 6 inches. As the palm grows older, the fertilizer application radius may be increased gradually up to about 5 ft. at the time of flowering. After the incorporation of fertilize with the soil, the entire manure circle of seedlings should be covered well with coconut husks, dried coconut fronds or other organic materials available in the estate.

Method of fertilizer application for adult palms

For maximum economy and efficiency of uptake of plant nutrients by the palm, fertilizer should be broadcasted uniformly on the soil surface within a radius of about 6 ft. from the base of the palm and incorporated with the soil to a depth of 4 - 6 inches using a mamoty or mamoty fork. Then the entire area of the manure circle should be mulched with either with coconut husks or dried coconut fronds. Unless weed growth is excessive, it is not necessary to clean weed round the palm before fertilizer application.

Application of fertilizer to adult palms

For details regarding recommended fertilizer mixtures, their doses and application methods refer the CRI Advisory Circular A 5 -Inorganic fertilizer application for coconut.

Time and frequency of fertilizer application

Generally, fertilizer is applied at the beginning or end of the rainy season (May/June, September/October) when the soil is moist. Coconut seedlings and young palms respond well to split application at 6 monthly intervals and annual application is recommended for adult palms. The efficiency of fertilizer use for adult palms could be enhanced with spit application if irrigation facilities are available. The recommended annual dosage could be split into a few applications for higher efficiency.

Organic and chemical fertilizer supplementation

To enhance the retention of plant nutrients applied to the manure circle, application organic and chemical fertilizer supplementation is recommended. The efficiency of chemical fertilizer applied could be increased with the combined application of both organic and chemical fertilizers simultaneously.

4.3 Improvement of soil quality

Coconut growing soil in Maldives is generally poor in organic content and major plant nutrients due to inadequate land and fertility management practices in major coconut plantations. Organic application has become vital in coconut cultivation in maintaining high production levels and soil health aspects. Organic manure application tends to increase the humus content in the soil, and supply plant nutrients. High humus content improves the water holding capacity, aeration, structure, micro-organism density, microbiological activities, and nutrient retention of soils. It also maintains the soil pH and temperature at favourable levels to coconut. Therefore, organic manures are important sources of plant nutrients, which help in sustaining soil fertility and productivity especially for perennial crops like coconut.

More details regarding the plant nutrient contents of organic manures, rate of organic application are given in CRI Advisory Circular A 6 - Use of organic mature for coconut.

Application of organic manure for young palms

In the early stages (up to 1-1 ½ years) organic manures should be broadcast up to 0.3 meters (about 1 feet) from the base and incorporate well with soil. As the palm grows older this area should be gradually extended up to about 1.5 meters (about 5 feet) up to the time of flowering.

Application of organic manure for adult palms

Organic manure and the inorganic supplements should be broadcasted in the entire area of the soil surface around the base of the palm up to 1.75 m (about 6 feet). The manure and inorganic supplementation should be incorporated into a depth of 4" – 6" of the soil. The area on which manure has been applied should be mulched with weed trash, dried fronds, layer of husks etc.

Organic manure could also be applied into a trench open around the palm. A circular trench of about 2 feet wide and 6 inches depth could be opened leaving 2.5 feet away from the bole of the palm. Soil is heaped up to form a circular bund around the trench. Recommended dose of organic manure and inorganic supplements equally broadcasted in the trench and incorporate well with the soil and mulch with dried coconut fronds or husks to cover the entire soil surface in the trench. The circular soil bund around must be maintained throughout to harvest rainwater and maintain moisture levels around the palm. The same trench could also be used to apply organic manure even in subsequent years.

Application of organic manure in a trench around a palm

Preparation of compost in coconut plantations

Most sandy soil types found in Maldives, where agricultural activities are carried out are structurally very poor in organic content resulting in low crop production and land productivity. Addition of compost to sandy soil types, improves the soil structure by make it more suitable for crop cultivation. Application compost to coconut to enhance nutrient status and the agricultural quality of soil is an essential requirement. Not only for coconut but also any agricultural project implemented in Islands require quality compost to increase the organic content of sandy soil.

Any organic material available in coconut lands could be used to make quality compost within plantations. Organic materials such as banana, papaya, coconut fronds, coconut husks, weeds, foliage from trees, shrubs, goat dung, and fish refuse could be used for compost making process after breaking them into small pieces with mechanical shredders. Nutritive value of compost could be increased further

by adding Rock Phosphate, in the process of compost making, to increase the phosphorus content and shredded coconut husks to add more potassium.

There are several compost making methods are used widely to produce quality compost with shredded organic materials as heap and pit systems. The crushed organic materials are placed on the ground as alternative layers with different materials and form a heap up to the manageable height. Compost heaps are applied with water to maintain the moisture level to increase the microbial activities on organic materials. The top part of the compost heap must be covered with black polyethene to maintain the temperature and prevent drying of heaps. An excavator machine is used to mix the materials in the compost heap time to time to expedite the compost preparation process. The first mixing is carried out after one month and second and third mixings were carried out after 60 and 90 days, respectively. Nitrogen rich leguminous lopping, goat manure, poultry manure and cow dung are used to improve the plant nutrient levels of compost. About 30 -40 kg of compost could be applied to a palm in circular trench cut around the palms. The compost must be mixed well with soil before covering with soil. Chemical fertilizers could also be applied with compost as a nutrient supplementation to coconut.

5. Soil and moisture conservation in coconut lands

Coconut palm requires regular supply of water to maintain a consistent nut production throughout the year. Naturally, water required for palms is supplied by the rain. Depending on the intensity of rain, part of the rainwater absorb by the soil and the balance water runs over the soil surface and connects to streams flows down the slopping areas causing soil erosion. As the rainfall availability is widely scattered, it is essential to adopt cultural measures to reduce surface runoff by rainwater and allow more water to absorb into the soils. Coconut roots absorb water available in the soil for its production and growth. The ability of retaining water in the soil depends on the type and the depth of soil where coconut is cultivated. Sandy loam and deep soils have the highest capacity of retaining water in the soil profile. Therefore, coconut palms cultivated in these soil types demonstrate good growth and high nut yield. However, shallow sandy soils with low content of organic matter could retain limited amount of water in the soil profile leading to poor growth and low nut production.

Stress conditions of palms due to drought

The symptoms of water stress conditions first appear in seedlings and then in young palms and eventually in adult palms. Drought can slow down or totally arrest the activity of the growing point of the crown. Leaf production is reduced resulting in lesser number of inflorescences immerged. Pollinated flowers are more susceptible to moisture stress conditions. Drought also arrests the formation of

flowers, and prolonged droughts or lack of soil moisture could cause immature nut fall. A long dry spell results in a reduction in not only the number of nuts but also their size.

The recovery after a severe drought is a slow process. Normal root absorption does not commence with the first rain. First, the growing points of the root will have to be reactivated from their enforced rest. The coconut production fluctuates widely with the availability of rain during monsoons and measures adopted to conserve soil moisture.

5.1 Methods of soil and moisture conservation

Mulching the manure circle

Mulching the manure circle of a coconut palm with dried plant materials is found to be the most effective method to conserve soil moisture within the most sensitive root circle. Conservation of soil moisture enhances activity of effective root zone of the palm resulting in higher nut production. Among the materials that could be used as mulch are weed trash, straw and fallen leaves of trees etc. Dried coconut fronds are the most easily and freely available materials in coconut plantations.

Benefits of mulching on the manure circle are reduction of moisture evaporation, soil erosion and soil temperature during the dry periods, suppressing weed growth and increasing organic matter in the soil.

Mulching with coconut fronds

Fallen dried coconut fronds should be cut into 2-3 pieces and used to cover manure circle. Button ends of dried fronds could be used as firewood. To ensure full coverage, 2-3 layers of coconut fronds are sufficient. With the decaying of fronds, the mulch could be maintained with new fallen fronds with covering area of 2 m radius around the palm.

Mulching with coconut husks

Fresh coconut husks have high manorial and useful properties to be used as a mulch. It also contains high amount of potassium, the most important plant nutrient for coconut. Use coconut husks just after husking without exposing them to rain. At the initial state, place about 200 husks in 2.0 m radius circle round the palm. Leave about 15 cm from the bole of the palm. For continuous maintenance of the mulch, add new husks to the mulch early. Two layers of husks are sufficient to obtain the full benefits. It is not necessary to arrange the husks neatly around the palm. When fertilizer is applied remove husk-mulch with a mamoty or a rake carefully (not disturbing decayed organic layer) and put them back with new

husks to maintain two full layers of husks. Do not apply husk mulch to palms in water logging areas. These palms can be identified by observing root mat close to the bole of the trunk.

Mulching manure circle with coconut fronds

Mulching manure circle with coconut husks

Application of organic matter

In addition to the supply of plant nutrients, organic materials (goat manure, cattle manure, compost) could be applied to conserve soil moisture. Water holding capacity of sandy soil types could be improved in many ways by mixing with organic matter. Clay soils are made loose and porous, thereby improves the aeration, drainage, and water intake. Organic matter also enhances soil microbial activities and recycling of minerals.

More details regarding the recommendations on soil and moisture conservation in coconut lands are given in the CRI Advisory circular A 9 - Soil moisture conservation in coconut lands (Annex 11).

6. Planting and management of bush covers (Leguminous trees)

Among fast-growing leguminous tree species *Gliricidia sepium* is recommended as a suitable and compatible bush cover, especially for moderately suitable and marginal coconut lands. The bushy type of canopy of Gliricidia is a desirable character for growing it successfully under the partial shade under coconut. In wet areas, it can be established conveniently by planting mature stem cuttings in 30 cm x 30 cm x 30 cm size pits filled with topsoil and few handfuls of organic manure. Prior to planting, gliricidia sticks may be cut back slantwise at the lower end to facilitate rooting. The most common method is to plant gliricidia of about 1.5 – 2.0 meters in length along boundary fences and in the avenue of coconut rows. In the coconut avenue, gliricidia sticks could be planted in double rows 60 cm apart in a triangular system. A notable feature is that gliricidia raised from cuttings develop a shallow-root system whereas those raised from seedlings develop a deep-root system with a prominent tap root.

Tree growth can be managed by regular pruning. Initial pruning of gliricidia may be done when trees are 12 – 18 months old at 1 m height. Thereafter, trees can be pruned regularly at 3 – 4 monthly intervals to produce a substantial quantity of biomass particularly rich in nitrogen. Regular pruning will also reduce root competition by mobilizing food reserves from roots to the development of new shoots. A well-managed gliricidia stand will produce about 8 – 10 tons of fresh leaf biomass per hectare per year which can be applied to coconut as valuable green manure or use it compost preparation.

Cultivation of Gliricidia plants in coconut lands as nitrogen rich green manure

7. Rainwater harvesting in coconut lands

Coconut palms require well distributed annual rainfall of 1500 mm for its average production. Accordingly minimum monthly rainfall requirement is about 120 mm. Major coconut growing areas normally receive rainfall in March, April, May, and September, October and November monsoons. In between main monsoons rainfall availability is very low causing water stress conditions in coconut growing areas.

Rainwater could also be harvested in manure circles of each palm. In this method 2 ft. circular trench with a depth of 6" could be cut about 3' away from the bole of the palm. The soil removed from the trench should be placed as a circular soil bund at the edge of the trench. One or two layers of coconut husks or fronds cut into 2 or 3 pieces are placed inside the trench where rainwater is accumulated inside the trench. When fertilizer is applied, drag the husk and frond mulch on to the edge of circular soil bund and broadcast fertilizer or organic manure inside the trench and mix them well with soil inside the trench. Drag the mulch back into the trench. Fertilizer application could be repeated annually in this manner at low cost and conserve more and more moisture inside the trench. The efficiency of fertilizer applied could also be increased.

8. Management of weeds in coconut lands

In coconut plantations only about 25% of the land area is utilized by coconut palms and the balance 75% is exposed to abundant of sunlight which allows the growth of a wide range of perennial and annual weeds. Such weeds invariably compete with coconut for soil-water and plant nutrients, thereby affecting its growth and productivity. In addition, presence of weeds will obstruct routine field operations such as fertilizer application, picking and collection of nuts and movements within plantations. Further, creeping weed species such as *Micania cordata* tends to climb and twine round coconut seedlings and young palms and suppress their growth. Heavy weed infestation often attracts rats and other vertebrate pests of coconut. Therefore, weed management in coconut estate is considered as an essential cultural practice in cultivation of coconut. In large coconut plantations, where the plantation is systematically established and usually maintained as a monoculture, weed invasion is more serious than in smallholdings. Although, weed management is one of the most difficult and expensive cultural practices, complete eradication of weeds in coconut lands is not possible.

Critical stage of weed competition

Generally, in young plantations more favourable environmental conditions prevail for rapid growth and persistence of weeds than in mature stands, mainly due to the availability of abundant sunlight. Also, weeds are aggressive, competitive, and difficult to manage during seedling and young palm stages. Therefore, the most critical period of competition by weeds is from planting up to about 5th year. It is reported that 64% reduction in growth of seedlings could be possible due to heavy weed infestation. Farmers are advised to pay more attention to understory weed management in young plantations than in mature plantations.

8.1 Common weed species

Many factors such as rainfall, soil type, age of plantation and the level of management affects the type of weeds present. Weeds are generally propagated by seeds or underground rhizomes. Among perennial grasses, *Imperata cylindrica* is undoubtedly the most noxious and troublesome weed species. Grass type grows vigorously and spreads rapidly in young plantations and senile plantations with abundant sunlight, particularly on sandy soils in dry areas. Foxtail/ Mana grass (*Pennisetum polystachyon*) is another perennial grass weed dominant in young plantations. It produces yellowish-green hairy inflorescences and deeply penetrating underground rhizomes.

8.2 Weed management methods

Slashing/mowing – Repeated slashing of aerial parts of weeds before producing flowers and seeds, at least twice a year either by hand operated brush cutter or tractor mounted rotary slasher. Rotary slasher can cover about 2 ha in 8 hours of a working day depending on the growth of weeds. In small plantations, small types of bush cutters could be used to slash weeds effectively.

Disc harrowing – Shallow ploughing followed by repeated disc harrowing is another effective method of suppressing understory weed growth on coconut estates. The dead mulch of weed trash covering the ground will effectively conserve soil moisture.

Mulching – To maintain the growth of weeds within the manure circle of the palm, the area around the palm up to distance of 1.5 m could be mulched well with dried coconut fronds, coconut husks, green lopping from tree branches.

Chemical methods

Among the range of herbicides (weedicides) available in the market, Paraquat (Gramoxone), Glyphosate (Round up) and Dalapon (Bsfapon) are effective and safe to be used around the base of young palms, as they become inactive when in contact with soil. Herbicides are generally used in the control of noxious perennial weeds. Weed management is more effective if herbicides are applied on to the growing new flush after slashing the mature aerial parts.

Grazing by animals

Livestock farming can effectively be used to manage weed condition in coconut plantations. This method is found to be profitable and sustainable in coconut plantations as an integrated livestock farming system. It is an effective and economical method of managing grass weeds on coconut estates and smallholdings. In the present situation where, free-range farming is gaining popularity, it can be introduced to coconut plantations where natural weed growth is high. Free-range farming with chicken, goats, sheep, and cattle could be carried out in large coconut plantations. The cost of weeding can be reduced by about 50% by grazing with livestock.

9. Coconut based farming systems

Most coconut lands are maintained as monoculture coconut plantations under rain fed conditions. Monoculture coconut cultivation is considered as an inefficient land management system, resulting in

low land productivity. The successful intercropping and livestock farming have proven to be the best options for maximizing land use in coconut plantations. The approach of coconut-based integrated farming system is promoted to maximize productivity per unit of land by optimizing the utilization of available resources, without causing any adverse effects on coconut. To make the best use of natural potentials available in coconut plantations, sustainable crop and animal-based farming systems could be introduced to existing large plantations aiming to enhance the overall land productivity.

Coconut based farming systems, involving cultivation of well-matched crops in the inter-spaces of coconut and integration with other enterprises like dairy, poultry and aquaculture offer considerable scope for increasing production and enhancing productivity per unit area, time, and inputs by more efficient utilization of sources like sunlight, soil, water and labour. Coconut based integrated farming is an ecologically sustainable system which helps the farmer to realize more income. Sustainability is the objectivity of the integrated farming system where production process is optimized through efficient utilization of inputs in safeguarding the environment with which it interacts.

10. Intercropping in coconut lands

10.1 Suitability of coconut Lands for intercropping

In coconut plantations, if palms are cultivated at the required distance and density the available resources such as sunlight, land, soil water and plant nutrient could be utilized efficiently by cultivating other crops in between coconut rows. It has been proven that coconut plantations over 25 years of age could effectively be used for the cultivation of a variety of spices, fruits and vegetables as intercrops, since the agro-climatic situations under coconut are high suitable for them.

Among plantation crops, the coconut palm by nature due to its growth and morphological characters is suitable for intercropping with a range of compatible crops and crop combinations. In a mature plantation where trees are spaced 8 meters apart, the active root zone is limited to a depth of 30-120 cm within an area of 02 m from the palm. It is revealed that, generally only 25% of the land area is effectively utilized by coconut leaving about 75% of unutilized fertile land in a monoculture coconut stand. The coconut canopy allows adequate light transmission to the ground among the palms, which normally ranges between 40 – 80%. For a given planting density and system, the amount of light transmitted to the ground varies considerably with the age of palms. Soil-water and plant nutrients available in coconut lands outside the manure circle, that remain untapped by coconut roots can be effectively utilized by intercrops having different rooting depth.

Dragan Fruit cultivation under coconut

10.2 General guidelines for intercropping under coconut

- Select intercrops according to the agro-climatic and soil type.
- Plant intercrops at least 02 meters away from the bole of coconut palm
- Apply recommended fertilizer mixtures separately for both coconut and intercrops
- Recycle crop residues from intercrops within the plantation

For further details regarding intercropping under coconut, refer CRI Advisory Circular C1, Intercropping in coconut lands (Annex 12).

11. Harvesting of coconut

Harvesting of mature coconut is not practiced in almost all the islands in Maldives. Only immature coconuts are harvested, by climbing or with portable aluminum ladders. To prevent damaging to immature nuts and keeping them in tacked in bunches, harvested bunches are lowered with help of a rope. However, in almost all other coconut plantations, it has been a common practice to wait mature nuts to fall and collect them for consumption or sale.

But in other countries where coconut is cultivated as commercial plantations, harvesting of mature coconut is the most important activity as it generates the main revenue of the plantation. Based on the level of plantation management nut yield level is determined. Coconut palm being a continuous bearer produces one mature bunch in every month which is ready for harvesting after about 12 months from the opening of inflorescence. Depending on the health of palm, soil and climatic conditions, the number of bunches that could be harvested from a palm in a year varies from 12 to 14. In dry periods coconut mature faster than in wet periods. Considering the bunch maturity pattern, the frequency of coconut picking is decided on the convenience of landowners.

11.1 Frequency of mature coconut picking

Coconut landowners could adopt one of the following frequencies in coconut picking.

Picking at two months interval (08 weeks) – bimonthly
This is the most common practice among small holders. Picking at two months interval, two bunches are harvested. One bunch is over matured turning into brown colour and the other bunch is also mature enough for harvesting. The number of picks in this system is 6 in a year. One of the disadvantages of this system is high fallen nut rate particularly in dry periods.

Picking at one month interval (12 picks in a year)
Experiments conducted at the Coconut Research Institute of Sri Lanka have shown that coconut picking at monthly interval has several advantages in terms of increasing the total nut yield, reducing fallen nuts and receiving the revenue monthly. Research has also shown that compared to bimonthly pick, the annual nut yield increase is over 25%. In monthly picking system only one bunch of each palm is harvested, therefore, the possibility of harvesting immature nut is minimal. In bimonthly picking palms have two bunches ready for harvest, one bunch is over matured turning into brown and the other bunch is also mature enough for harvest. The palm must sustain one over matured bunch for extra one month by using its energy and food. In monthly picking as only one bunch is harvested the extra energy and food contribute to develop more nuts in bunches and enhancing nut settings. This physiological impact in the palm, eventually uplifts the annual nut yield over 25%. This increased yield should compensate the extra cost involves in 12 picks, instead of 6 picks in bimonthly. The cost of picking must be negotiated with pickers.

11.2 Methods of coconut picking

Picking with bamboo poles

In commercial coconut cultivations in other counties coconut picking is mostly carried out with a set of seasoned bamboo poles in different heights. Mature straight bamboos are cut and treated with withering on fire are used as picking poles. When the palms are very tall, pickers make the pole taller by tying number of poles together to reach crowns even up to about 60 feet. Curved sharpen knife made up of with quality steel, is tied to the top of the pole. Pikers need special skill to handle a tall bamboo pole with a knife on the top weighing about 5 to 10 kg and moving palm to palm harvesting correct bunches. Coconut harvesting with bamboo poles is less expensive compared to climbing.

Picking by climbers

This is mainly done in small holdings and harvesting of immature coconut for the beverage purpose. In large coconut plantations, climbers are employed to harvest very tall palms which cannot be harvested with bamboo poles. Skilled people climb up to the crown and cut mature bunches with a curved knife. Picking with climbers is an expensive operation as pickers charge per palm bases.

Collection of fallen nuts

In Maldives, as mature coconut picking is not practiced in coconut growing areas, mature nut falling is taking place throughout the year. But in most plantations, the collection of fallen nuts is hampered due to high growth of weed-undercover in between coconut palms. But in plantations, where the undergrowth is cleared, fallen nut collection could be carried out at regular intervals. In large plantations, it is important to employ labourers to collect fallen nuts daily until the next pick. Fallen nuts are to be counted, recorded, and heaped in separate place.

Annex 4

MONITORING OF WHITEFLY INFESTATION IN THE FIELD

Follow the following steps in periodical monitoring/ assessment of the whitefly infestation in the field.

1. Identify 3 locations with whitefly infestation in the coconut growing area in each island.
2. In each location select and mark 3 infested palms for sampling.
3. In each marked palm count the number of infested leaves.
4. Sampling
    a. From each palm cut two leaves/ part from the lower and mid whorls (take care not to disturb the whiteflies too much).
    b. Collect 2 infested leaflets from each frond.
    c. Count the number of adult whiteflies on each leaflet immediately after cutting the leaf.
    d. Collect the leaflets in perforated polybags and label for later examination.
5. Carry out sampling, every 2 months until infestation subsides.
    a. Observe samples using a microscope (it may be necessary to wipe off some cottony filaments on the colony with a fine hairbrush to observe the insects clearly)
    b. Count the number of immature stages and live (yellow colour) puparia
    c. Count the number of puparia with parasitoid emergence holes
    d. Count the number of blackened (parasitized) immatures/ puparia having no parasitoid emergence holes
6. Record observations for each location.
7. Continue assessment, monitor and take action.

Date: Location :

Palm no.	No. of leaves infested	Total no. of adult whiteflies	Total no. of live immatures and puparia (A)	Total no. of puparia with emergence holes (B)	Total no. of parasitized immatures/ puparia (C)	Remarks (any predators etc)
1						
2						
3						

Infestation index;

Low – < 10 whitefly adults per leaflet , 5 - 6 fronds infested

Moderate – 10 - 20 whitefly adults per leaflet, 10-12 fronds infested

High - > 20 whitefly adults per leaflet, >12 fronds infested

Parasitism levels:

If, C/ (A+C) = >50% - high, 30-50% - moderate, <30% - low

Parasitoid activity levels:

If, B increases over time-	parasitism increasing
B constant over time	parasitism stagnant
B decreases over time	parasitism decreasing

Actions required:

Continue assessment and monitor the change in infestation level, parasitism level and parasitism activity.

1. If no parasitism (zero), spray the palms with neem oil mixture.
2. If parasitism level is high (>50%) no action required, continue monitoring.
3. If parasitism level is low (<30%), infestation Index is moderate/ high release parasitoids.
4. If parasitism level is low (<30%), infestation Index is low, parasitoid activity (B) constant/decreasing over time release parasitoids.
5. If parasitism level is moderate, infestation Index moderate/ high and parasitoid activity stagnant/ decreasing consider releasing parasitoids.
6. In other scenarios keep monitoring and take necessary action when necessary.

Infested palm

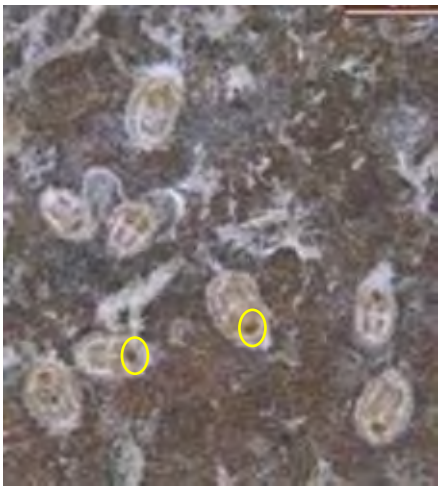
Whitefly infested frond (lower surface)

Whitefly colony on coconut leaflet

Adult whiteflies (RSW and BNW)

Immatures and parasitized pseudo pupa

Pseudo pupa (unparasitized)



Pseudo pupae with parasitoid emergence holes

Parasitoid *Encarsia guadoloupe* (0.6 cm)

Annex 5

MASS REARING METHOD FOR ENCARSIA GUADALOUPE A PARASITOID OF RUG OSE SPIRALING WHITEFLY

The parasitoid, *Encarsia guadaloupe* has been reported as an effective natural enemy of the RSW and natural parasitism levels over 60% has been achieved. It is present in the Maldives and parasitizing RSW.

There are no reported methods of mass rearing of the parasitoid elsewhere. Rearing them for research purposes has been reported in Florida and India. Therefore, it is suggested to initially rear them in laboratory scale and then scale up depending on the requirement.

To breed the parasitoid, it is first necessary to rear RSW. The methodology of rearing RSW is given below.

i. Selection of a suitable host plant for rearing

RSW has several host plants including coconut. Therefore, it is suggested to select the host plant that RSW develops well in caged conditions, easily available in the Maldives. It is suggested to use healthy coconut seedlings, banana, guava, sapoda, papaya, wild hibiscus and any other that is known to colonize by RSW in the Maldives.

ii. Preparation of cages for rearing

- Prepare 6 cages of 1,8 m wide, long and heigh.
- The floor of the cages should be strong enough to hold the potted plants.
- Cover all sides with insect proof net.
- Construct a door (insect proof) on one side of the cage.

iii. Introducing RSW into cages

- Keep the cages under shade, but with sufficient sunlight for the plants to survive. In this case cover the top of the cages with transparent and waterproof sheet. Alternatively, mesh cages could be kept inside an open shed with a roof (see photo).
- Fertilize and water the plants to be used for rearing.
- Lay the host plants (about 6 plants) in each of 3 cages.
- Collect portion of coconut fronds or leaflets infested with RSW (with large number of adult whiteflies present) from the field.

- Place the infested leaves inside the cages. Also, in a separate cage introduce the RSW adults (100 – 200) collected from the field.
- Check the leaf surface of plants for egg spirals of whitefly.
- Add infested leaves every week for 3 weeks. In the cage introduced with RSW adults keep introducing 50 – 100 each week, 3 times.
- Observe the plants every 3 days to check the development of whitefly (generally RSW takes about 20 – 25 days to reach the pupal stage).
- Choose the plant/s that has higher number of RSW insects.

If the above method of infestation of host plants fails, it is suggested to use an infested potted plant (source plant) with RSW adults instead of infested leaf fronds or leaflets. It is said that this method is more successful in infesting host plants (Taravati *et al.,* 2018).

Infesting source plant with RSW

i. Use a wood box, about 78 × 38 × 45 cm (W × D × H) with a glass top.
ii. Place a potted plant of banana/ coconut inside the box.
iii. Place leaves of coconut/ banana or ficus with RSW inside the box for oviposition on source plants.

Once the suitable plant is chosen, rear RSW on those plants in cages until the method of RSW rearing is perfected. It may be necessary to change to location of cages, cage type/ dimensions, number of plants in a cage and RSW introducing interval etc.

After perfecting the rearing method of RSW, rearing of the parasitoid could be commenced. The method of rearing is given below.

i. Introduction of parasitoids
    - Collect 100 – 150 parasitized RSW pupa (black in colour) from the infested leaves in the field into a small vial.
    - Place the vial inside the RSW infested cage. For the introduction of the parasitoids the culture RSW should have last stage immatures (about 15 days after egg hatching).
    - The parasitoids emerge from the puparia will lay eggs in the body of immature RSW and develop inside it. The RSW larvae will be killed. The parasitized puparia will turn black in colour.
    - Check the RSW culture every week after introduction to check for parasitism.
    - Release about 100 field collected parasitized RSW pupa, two times in 3 - 5 days apart.

- Collect parasitized puparia in vials for field releases.

For field releases, collect about 100 puparia in vials with open lid and hang them on leaves/ trunks of infested palms, in areas where parasitism levels are low or none.

Once the small-scale mass production technology is perfected it could be scaled up. For large scale mass production, it is recommended to use insect proof screen houses, separately for RSW production and parasitoid production.

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Annex 6

Rugose Spiralling Whitefly (*Aleurodicus rugioperculatus*)

Rugose Spiralling whitefly is a new introduced pest of coconut in the Maldives. It is known as a serious pest of coconut causing yield losses in other countries where it is present.

Symptoms of Damage

The Rugose Spiralling Whitefly (RSW) infests the leaves of coconut and in severe instances it even attacks the nuts. Coconut palms of all ages are vulnerable to attack. The damage to coconut is caused by the immature stages of the pest. The immature whitefly feeds on the lower surface of leaflets by sucking its sap. Due to a large number of immatures feeding on leaflets the feeding areas of the leaflet turn yellow. These yellow patches coalesce and later dry off. When the lower surface of leaflets is examined, it could be identified by the presence of heavy white, waxy material. While feeding the immature whitefly excrete a sticky sugary substance called honeydew and it could be observed around the infested area. Black sooty mould grows on the honeydew covering mainly the upper surface of infested leaflets in black colour crust like material. The infestation starts from the lowermost leaves of the palm and spreads upwards with its progression.

Another whitefly species, which is smaller in size (1 mm) to RSW is present co-existing in the colonies of RSW. This species is identified as *Paraleyrodes bondari*, commonly known as Bondars' Nesting Whitefly (BNW). The damage symptoms caused by this species is similar to that of RSW.

Yellow colour patches on leaflets

Coconut leaf with sooty mould

Coconut leaf infested by RSW

RSW colony

Biology of RSW

RSW has egg, nymphal, pseudopupal and adult stages. Total developmental time is 56 -58 days on coconut.

Adult

RSW adults are about three times larger (approx. 2.5 mm) than the commonly found whiteflies and are lethargic by nature. The adults can be distinguished by their large size and the presence of a pair of irregular light brown bands across the wings. Males have long pincer-like structures at the end of their abdomen. Adults live about 20-21 days.

Eggs

Female RSW lays eggs on the underside of leaves in a concentric circular or spiral pattern and cover with white waxy matter. Each egg spiral contains about 30 eggs. Eggs are elliptical and creamy white to dark yellow in colour. The length of an egg is about 0.3 mm. and hatch in about 8 -9 days.

Nymphal (immature) stages

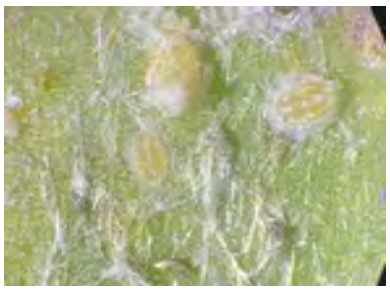
RSW has 3 nymphal stages. The first stage, known as the crawler stage (because it is the only mobile immature stage) hatches out of the egg and move a short distance to find a suitable site for feeding. It has functional legs. Crawlers moult into the second nymphal stage. Second and third nymphal stages are immobile, oval, and flat initially but become more convex with the progression of its life cycle. The nymphs are light to golden yellow in colour, and produce a dense, cottony wax as well as long, thin waxy filaments which get denser over time. Size of nymph varies from 0.34 mm to 0.9 mm in length from first to third instar. The nymphal period lasts about 17 -19 days.

Pseudo pupa

The last nymphal stage is called pseudo pupa. This stage lasts about 10-11 days. It is about 1.2 mm in length and 1 mm in width. Pseudo pupa is also sedentary and yellowish in colour. Body is densely covered with white waxy material. Adult emerges from the pseudo pupa through a 'T' shape exit hole.

RSW adult

Egg spirals of RSW



Nymphs of RSW

Pseudo pupa of RSW

BNW adults and its nestin habit

Host plants

In addition to coconut, RSW attacks many plants. Some are banana, betel nut palm, fan palm, guava, mango, Ficus, wild hibiscus etc.

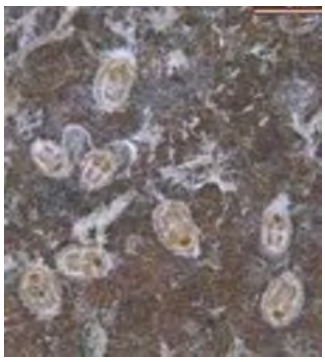
Integrated management

Biotic and abiotic factors play a complementary role in suppressing RSW and BNW populations. High rainfall and humidity reduce the pest population while high temperatures favour its build up.

Several biological control agents, parasitoids and predators have been reported in controlling whitefly populations effectively. In the Maldives the parasitoid, *Encarsia guadaloupe,* which is a parasitoid of RSW is present. The female parasitoids lay eggs in the body of immature whiteflies feeding on coconut leaves and develop in them killing the pest. A parasitized pseudo pupa appears black in colour and could be distinguished from unparasitized pseudo pupa. After about 2 weeks the adult emerges making a small hole on the pseudo pupa. The parasitoids are free living and fly from tree to tree looking for whitefly immatures to lay eggs. *E. guadaloupe* is about 0.5 mm in size. It has dark brown to black body with a triangular shape yellow part of thorax. As the cycle continues parasitoid numbers build up gradually and suppress the whitefly population. Natural increase of parasitiods as well as augmentative release of mass bred parasitoids could bring about effective control of RSW over time.

Parasitoids of BNW have not been reported yet. However, few types of coccinellid beetles were found associated with colonies of whitefly. Coccinellid beetles are reported as predators of whiteflies. Hence, it is essential to conserve these biological control agents in the environment.

In areas where parasitism is not found, it is recommended to spray 1% neem oil and 0.5% soap solution to thoroughly wet the palms. Spraying should be repeated at 2 -monthly intervals until the infestation ceases. In India, spraying of 1% starch solution to leaflets has been recommended to flake out the sooty mould.



Pseudo pupa with parasitoid emergence holes

Parasitized RSW pseudo pupa

E. guadaloupe adult

Annex 7

Management of *Oryctes* beetle

Oryctes beetle, scientifically known as *Oryctes rhinoceros* L**.** is also commonly known Coconut rhinoceros beetle, Asiatic rhinoceros beetle and black beetle. The beetle is indigenous to the Maldives and widespread in most coconut growing islands. It causes economic damage to the seedlings and young palms, resulting in retardation of growth of the young palms and even death of seedlings. Generally, *Oryctes* beetle damage on adult palms will not contribute to economic crop loss, unless severe and repeated damage occurs. Damage to palms is done by the adult beetle feeding on the bud region of the coconut palm.

Identification of life stages

Adult beetle is nocturnal. It can be easily identified by the black colour body and the head bearing a characteristic prominent backwardly directed tapering horn. The female beetle lays 90 - 100 small whitish globular eggs in decaying organic matter such as decaying coconut logs, organic manure heaps, fiber dust and husk heaps etc. Eggs are hatched in 8-12 days. The emerging grub has a whitish body bearing three pairs of legs and a dark brown head. It has a characteristic 'C' shape when resting. Fully grown grub is about 2 cm. long. The grub / larval stage lasts for about 3 months. The grub eventually makes a hard spherical shaped cocoon using soil and organic matter and pupate inside it. After about 3 - 4 weeks, adult beetle emerges from the cocoon. The adult beetle lives for about 3 - 4 months.

Adult beetle

Eggs

Larva

Pupa

Larvae in organic matter

Nature and identification of damage

The adult beetle bores and enters the soft area at the base of the bud, continues feeding on the soft tissues, resulting damage to the folded leaves and their petioles. At the opening of the burrow, fibrous materials that have come out from the burrow could be seen. When the damaged leaves unfold, they exhibit characteristic 'V' shaped geometric cuts. Sometimes holes on the leaf petioles could be found. If the damage to the petiole is extensive, breaking of the flag leaf hanging on the crown could be seen. The damage often causes choking of the developing leaves in seedlings, resulting in the formation of crooked and malformed leaves leading to retardation of growth of the seedling. The damage to the growing tip of seedling is fatal.

Chewed up fibres on the beetle entrance hole

Geometric cuts on leaves

Holes on the leaf petiole

Hanging of bud leaf

Crookes leaves of a damaged seedling

Integrated Management

Use of one management method is not sufficient to control *Oryctes* beetle effectively. Hence, it is recommended use of several methods interestedly.

1. Estate sanitation

   Breeding grounds of black beetle should be removed from the coconut growing areas. Coconut logs and husk, fibre dust, saw dust, cow dung and any decaying organic matter will act as breeding grounds of the beetle. If logs are used as fencing poles, they should be painted with coal tar. If any organic material is used as fertilizer or mulch, it must be spread into a thin layer or covered with a thick layer (2 cm) of soil. Mulch should be routinely examined and if larvae are found they should be destroyed.

2. Extracting of beetles

   Seedling and young plantations should be examined frequently for *Oryctes* beetle damage. The chewed up fibrous matter or 'frass' at the base of the tree and around the entry hole are indications of the damage. It is likely that adult beetle is inside the bud if fresh frass is present at the entrance hole. In such instance, the beetle should be removed using a pointed metal hook.

Hooking out of beetle

3. Repelling of beetles
   (i) Repelling of beetles could be done by application of used engine oil or coal tar on the base of 2 - 3 innermost leaves (Caution: Do not let the chemical drip in to the bud region, which may kill the seedling).
   (ii) Place 2 naphthalene balls each at the leaf axils of the 3 leaves closest to the bud. Make sure to replace the naphthalene balls and move into the new fronds regularly. This method is more suitable for home gardens.

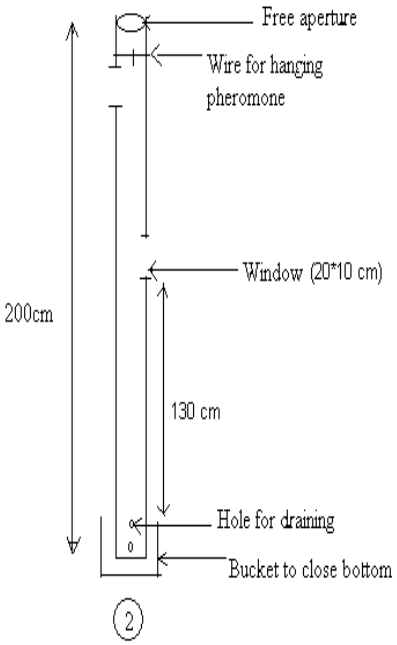
Use of insecticides are not encouraged as they are toxic to humans and animals. However, if necessary, when severe damage is noticed the following insecticides could be used.

4. Mass trapping of adult black beetles

Oryctes beetles could be trapped in large numbers using pheromone-baited traps. The adult female beetles produce a chemical called pheromone to attract male and female beetles. This pheromone is synthetically produced and available in the market to use in the traps to attract *Oryctes* beetles. In Maldives, currently, the *Oryctes* beetle damage is not high, hence the pheromone trapping could be used for a short period until the damage reduces to a very low level.

To install the pheromone, a trap made of PVC pipe of 15 cm. diameter and 2 m length is used. Two windows of 20x10 cm. are cut on the either side of the pipe at about 130 cm and 180 cm. from the bottom. The pheromone is hung on the topmost window. On the bottom few holes are made for drainage and the bottom is closed with a perforated bucket or cap. The trap should be examined every 2 - 4 weeks and remove the beetles trapped. The pheromone sachet must be replaced in about 3 months when it becomes empty. Use of 1- 2 traps per hectare is sufficient.

Manufacturers of *Oryctes* pheromone is found in the web. Pheromone is proved to have no effects on humans, animals, or environment. It is only specific to *Oryctes* beetle.



A diagram of a pheromone trap

Installation of pheromone trap

5. Biological control

There a virus (OrV) and a fungus (*Metarhizium anisoplie*) infecting and killing *Oryctes* beetles. The beetles should be fed with the virus suspension to infect. Infected beetles could be released to spread the infection within the *Oryctes* population. The method of infecting beetles is given in a previous leaflet published by the Ministry of Fisheries, marine Resources and Agriculture. This method may not be convenient for the farmers to carry out by their own. The commercially available fungus could be sprinkled in breeding grounds of the beetle. When contact with the fungus adults, larvae and pupae get infected and die. The breeding ground act as a reservoir of the fungus as it could survive for a long period if suitable conditions (wet conditions) prevail.

Annex 8

Control of rats in coconut plantations

Rat damage is widespread in most islands of the Maldives. Although, rats damage both nuts and seedlings of coconut, in Maldives rat damage is found only on nuts. Tender nuts of all ages are prone to damage but nuts of 3 - 8 months old are more vulnerable. Rats knaw into the developing nuts and feed on nut water and kernel. As a results nuts fall prematurely. Certain varieties of coconut such as king coconut and dwarf varieties are more attracted to rats. Rats cause direct economic loss to coconut.

Control

Satisfactory control of rats in coconut cultivations are not easy in many situations, especially in Maldives where forest barriers are maintained for environmental protection. But continuous practicing of different methods of control would give successful results.

1. Estate sanitation

Weedy areas with plant debris, palm logs, tree trunks, husk heaps are ideal habitats for breeding of rats. Since such areas are plenty in the islands, practice of estate sanitation by removal or burning of such material in the cultivations and keeping the ground free from weeds and debris is a very important cultural method in rat control.

2. Trapping

Trapping is useful in home gardens. Traps may be either place on palm crowns or on ground. Various kinds of rat traps such as wire frame drop-door cage traps and foldable aluminium traps are available.

i. Crown trapping

In this method the trap is set up on the crown of palms damaged by rats. The trap can be hoisted on the crown in a such a way that it can be lowered when required, using a pully. Commonly used baits are copra, partly burnt coconut kernel, roasted bread, dried fish.

ii. Ground trapping

Traps with bait is installed on the ground.

3. Baiting

Rodenticides are generally used in baits. First, baits without poison are offered 3 - 4 times for the rats to get accustomed to the bait. Then the poisoned bait is offered. Various kinds of rodenticides are

available in the market. Precautions should be taken when using chemical as they are highly poisonous to humans and animals.

i. Crown baiting

Plastic bags containing the bait is placed on the crown of the palm at the axil of a frond, in the region where the bunches are vulnerable to damage. Monthly placement may be necessary. Generally, baiting of 10% of trees may be sufficient.

ii. Ground baiting

Traps are set up on the. The poisoned bait is contained in receptacles such as coconut shells and place on the ground, proximity to the damaged palms where rats are likely to reach them. A suitable cover should be placed over them to protect from rain, and it should be kept out of reach of children and house animals.

4. Banding

Banding could effectively be reduced rat damage in individual trees. This is a method that a band is wrapped around the trunk of palm to prevent rats from climbing up. Before rat bands are fixed, crown should be cleaned and remove all rats and their nests. Also, it is essential to cut the fronds touching other palms, trees and any structures, because it can allow cross over of rats. The bands should be slippery enough to prevent rats passing over it.

i. Rat bands are made of galvanized iron sheets of 30c m. m wide and fixed around the trunk of palms at a height of about 1 m. from the ground. The band could be fixed to the trunk by a metal wire, but it should not allow the rats to step on.

ii. Instead of galvanized sheet, banding the stem with 30 cm wide polythene sheet of 500 gauge at 1 m. above ground level could also be used.

Nuts damaged by rats

Metal banding of trunk

Annex 9

PROCESSING OF COCONUT PRODUCTS

1. Tender coconut

The perishability of tender coconut is relatively high and once the tender coconuts are detached from the bunches the natural freshness gets lost within 24 to 36 hours, even under refrigerated conditions unless treated. The bulkiness of tender coconut is due to the husk which accounts for two-thirds of the volume of tender nut. Handling of tender coconuts is easy if a major part of the husk is removed. But, when partial removal of husk is done the colour of the nut is changed to brown thereby reducing the attractiveness of the nut.

Technologies for minimal processing of tender coconut have been developed to retain the flavour and prevent discoloration. The process involves dipping (partially) de-husked tender coconut in a solution of 0.5% citric acid and 0.5% potassium metabisulphite for three minutes. The product can be stored for up to 24 days in refrigerated condition at 5 - 7^0 C. By using this process tender coconut can be transported to distant places and served chilled like any other soft drink. Uniform size of nuts facilitates the use of plastic crates and insulated chill boxes for transporting and storage. In Thailand young coconuts are trimmed, treated, and packaged with an opener, straw, and spoon and are commercially produced and marketed (even exported) to countries like Australia, Europe, Japan, USA, Taiwan, Hong Kong etc (Muralidharan, 2019).

Preservation and packing of tender coconut water in pouches and aluminium cans has been succeeded in retention of its flavour. When packed in pouches/aluminium cans for three months under ambient conditions and six months under refrigerated conditions (Muralidharan, 2019).

Tender nuts with husk partially removed

2. Coconut water from matured coconut

Small-scale coconut water collection, preservation and bottling is given in the Fig.1.

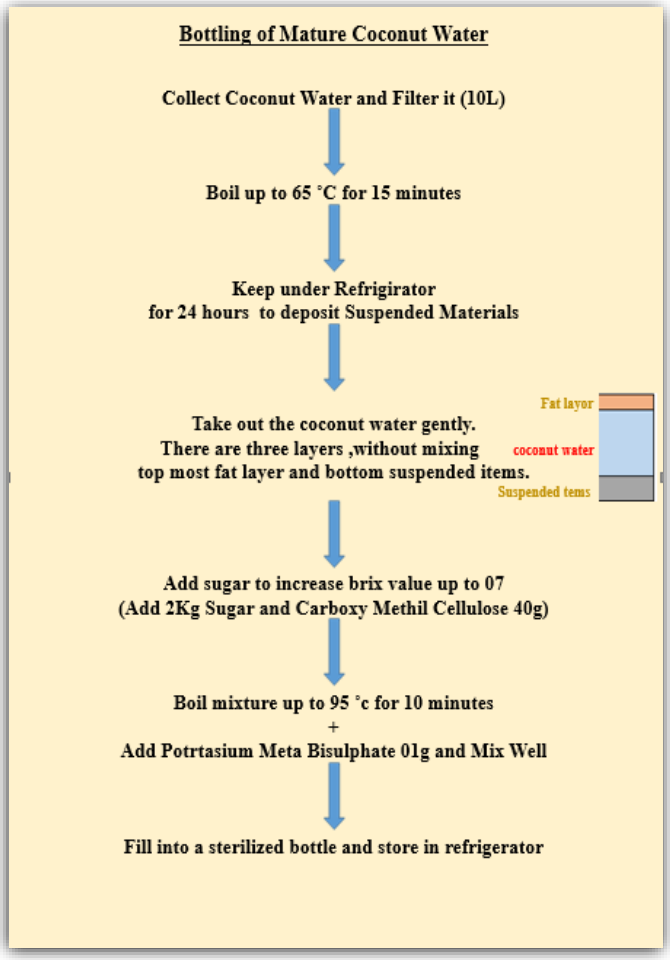


Figure 1. Bottling of mature Coconut Water
Source: Coconut Research Institute in Sri Lanka

3. Virgin Coconut Oil

Wet Processing method

Wet processing of coconuts is a new process of oil extraction from fresh matured coconuts producing high-value, high-quality Virgin Coconut Oil (VCO) rich in vitamin E and possessing a long shelf-life period of one year. One liter Virgin Coconut Oil (VCO) is obtained from 12 fully matured, fresh coconut kernel by mechanical or natural means with or without application of heat which does not lead to alteration of the oil and its properties. The Fig. 2 depicts the production of virgin coconut oil in cottage industry.

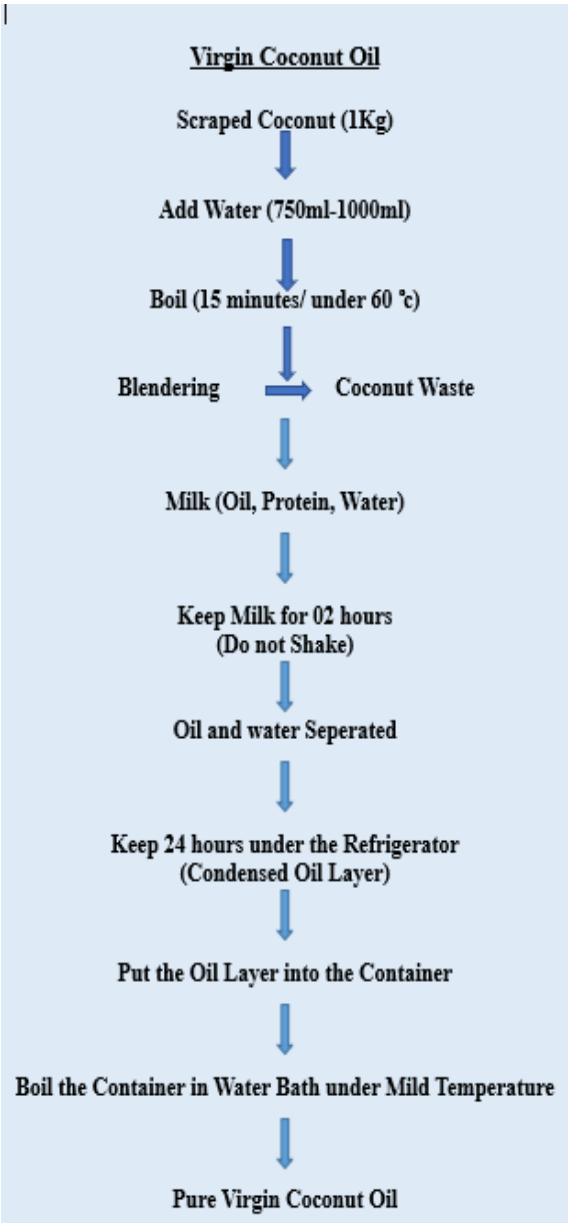


Figure 2. Virgin Coconut Oil production process

4. Coconut oil

Coconut oil is extracted from dried coconut kernel known as copra. Copra is made by drying and seasoning the coconut kernel using different methods. This is referred to as curing. Oil is extracted from copra by subjecting it to high pressure under a mechanical press. This operation is called "oil expelling". The oil is then steamed or heated to deodorize the oil and “bleached” by filtering through clays to remove impurities and any remaining bacteria. Sometimes chemical solvents such as hexane is used to extract oil from copra. The resulting oil has a higher smoke point of about 400-450^{0}C. The flavourless and odourless oil is popular in several trending diets. In addition, traditionally most households in Maldives boil coconut milk to separate the coconut oil for edible purposes and application as body moisturizers.

5. Coconut Paste - Dry processing

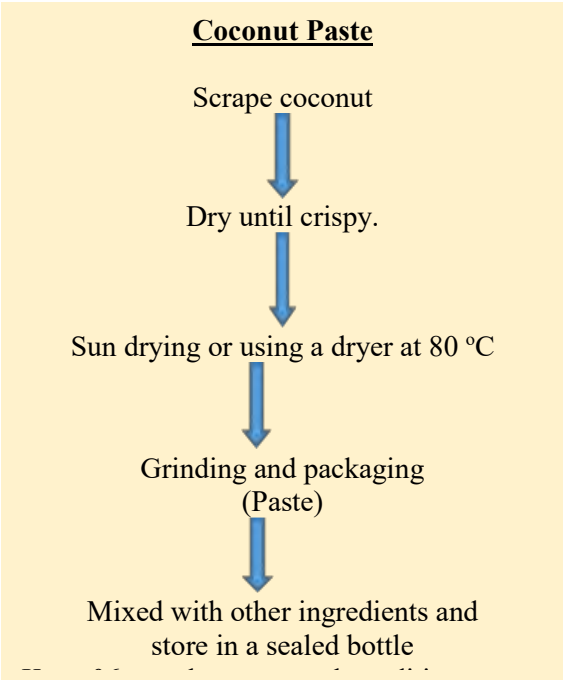


Figure 3. Coconut paste production in domestic level

6. Coconut Sugar

To recover raw sugar, toddy is treated with 2% lime to coagulate albuminous impurities. The limed toddy is then carbonated in two stages and filtered each time to remove excess lime. The clarified juice is evaporated to obtain 75% sugar content and the resultant syrup is concentrated in vacuum pans till crystallization commences. The syrup is then discharged into crystallizes and the crystalline sugar is separated by centrifugation. The production process is given in Fig. 4.

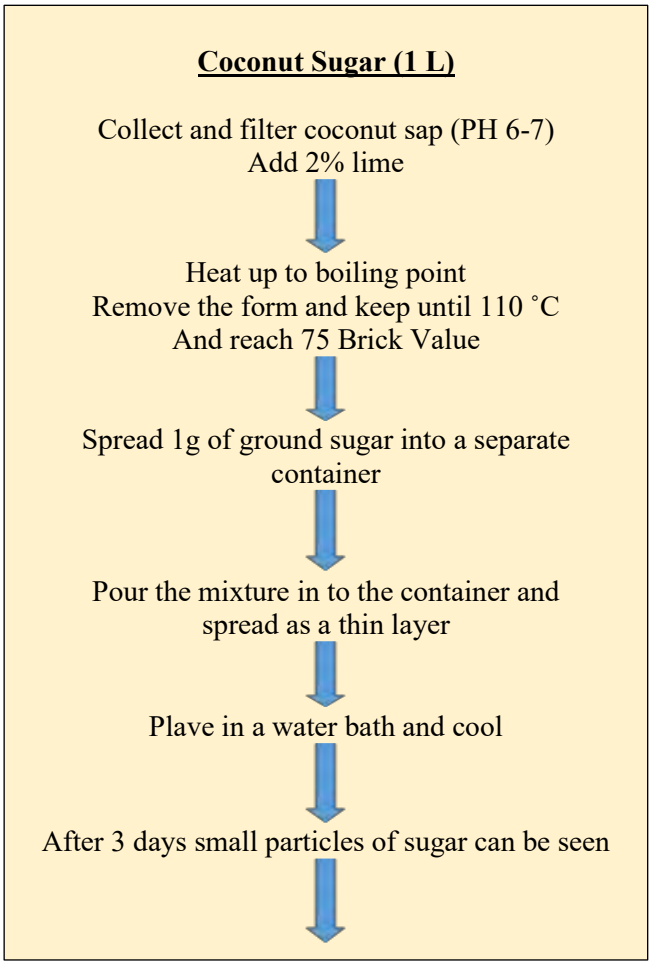


Figure 4. Coconut Sugar Production in the domestic level

7. Coconut Treacle and Jaggery

Inputs for coconut treacle and jaggery is the coconut sap. For jaggery production pH value should be above 5.5 and for coconut treacle production it should be above 4. Fig. 5 depicts the processes of the product.

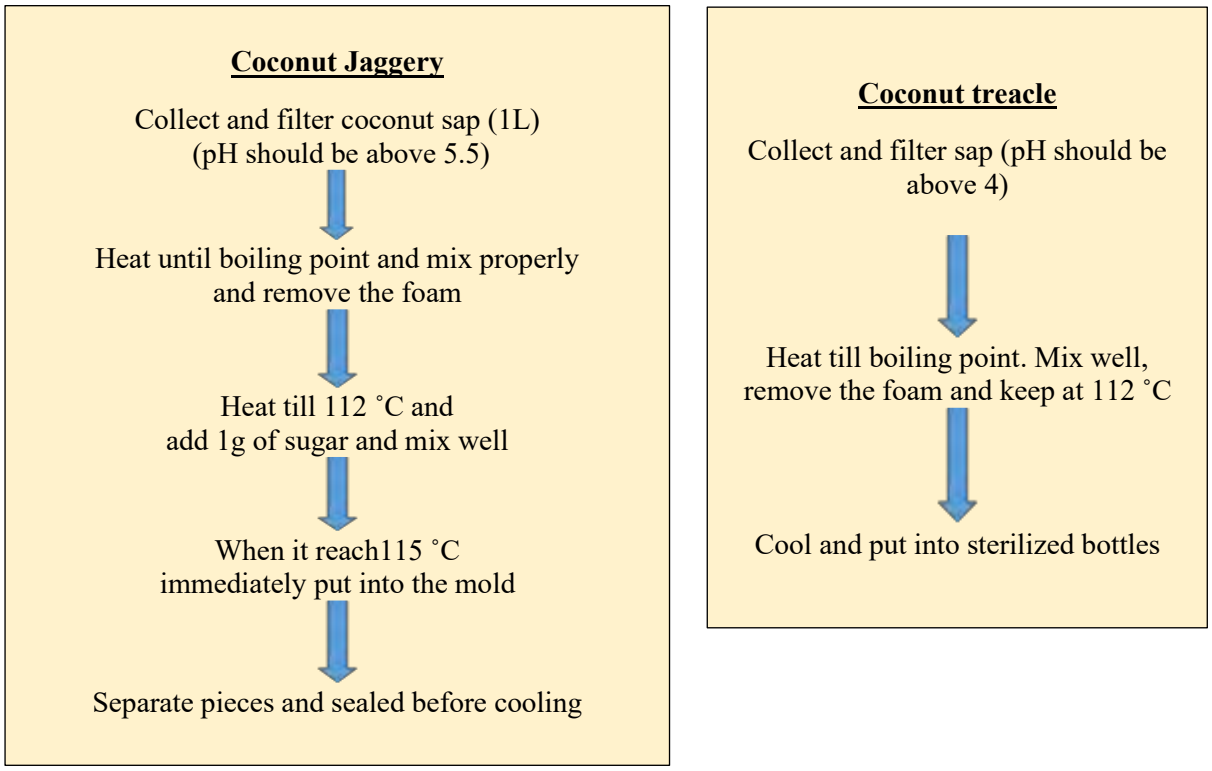


Figure 5. Coconut Treacle and Jaggery production process in cottage industries

Source. Coconut Research Institute Sri Lanka - 2016

8. Coconut Ice Cream

Coconut ice cream is very popular in Thailand, China, Sri Lanka, and other countries This is made up of 100% pure coconut milk. This is suitable for lactose intolerance and vegetarians**.** Processes of production of ice cream and jam are given in Figs. 6 & 7.

Coconut Ice Cream

Coconut milk 4 l (1200 g of kernel)

↓

Boil up to 50 ^{0}C

↓

Add 01 kg of sugar
+
Gelatine 26 g
+
40 g of corn flour, 12g of salt
boil up to 90 ^{0}C

↓

Add 26 g of margarine and 4 g of vanilla essence
keep for 2 - 3 minutes

↓

Cool down to room temperature
Add coloring and flavours
Put into ice cream machine

Figure 6. Coconut Ice cream production process

Coconut Jam

Half-matured coconut kernal
(07-08 months old nuts)

↓

Remove the testa and wash the kernal

↓

Grind the kernal with 200 ml Water

↓

Coconut paste

↓

Add 500ml sugar syrup

↓

Slightly heat the mixture until dense (Bricks – 65)
+
Add 5g of Pectin
and
Citric Acid 4 g and mix throughly

↓

Fill into sterilized bottles

Figure. 7. Coconut Jam production process
Source. Coconut Research Institute Sri Lanka - 2016

9. Coconut Yogurt

The production process is given in Fig. 8.

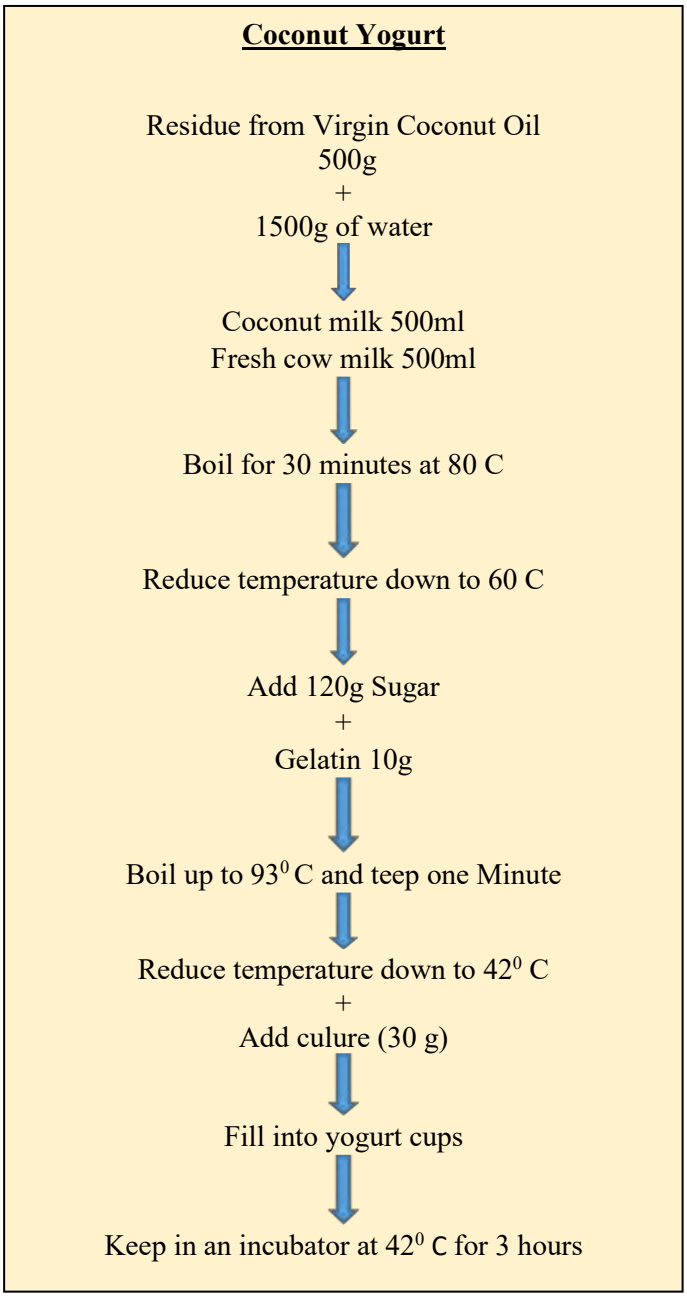


Figure. 8. Coconut Yogurt production process

Reference

Muralidharan, K., Subramanian, P., Machew, A. C., Thamban, C., Jayasekhar, S., Krishnakumar V., Madhavan, K. (2019). Upgrading a Coconut Value Chain: Empirical Evidence from North Kerala. International Journal of Innovative Horticulture. (1):72-80. https://api.semanticscholar.org/CorpusID:210136099

Annex 10

CASH FLOWS OF VALUE ADDED PRODCUTS

Cash Flow of Virgin Coconut Oil Production at Dodangaslanda Area Estates												
Income	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11-20**
No. of mature nuts		600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000
Oil output (Liters)												
VCO - 50% of total nuts (to produce 1 liter of VCO, needs 12 nuts)		50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Main income;												
VCO @ Rs. 1100/- per litter		***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***	***55,000,000***
By products income;												
Coconut shells output (Kg) @ 8 shells per 1 Kg		75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Coconut shells income (Rs.) @ Rs. 20/- per 1 Kg		***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***
Testa output from VCO (Kg); 450,000 nuts * 0.05 Kg		30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Testa income (Rs.); Rs. 110/- per 1 Kg		***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***	***3,300,000***
Oil cake output from VCO (Kg)												
Oil Cake 450000*0.350kgs = 210000Kgs *50%=105000Kgs Dry Delectated Coconut *30% = 31500Kgs Oil Cake@100/-		15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750
Oil cake income form VCO (Rs.)		***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***	***1,575,000***
Total income (Rs.)	***0***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***	***61,375,000***

Cash Flow of Virgin Coconut Oil Production at Dodangaslanda Area Estates												
Expenditure	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11-20**
Cost of nuts @ Rs. 50.00/-		***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***
Cost for loading;												
No. loads ; 1,200,000/2,000 @ 2,000 nuts per 1 load		300	300	300	300	300	300	300	300	300	300	300
Cost; (0.5 labor per 1 load) (Rs. 1,011/- per head)		***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***
Cost for transport (1.5 T/hrs per 1 load; 650/- per 1 T/hrs)		***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***
Cost for de-shelling @ 2,000 nuts per labor @ Rs. 2,500/- per head		***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***
Cost for pairing @ 2,000 per labor @ Rs. 2,000/- per head		***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***
Cost for washing;												
10,000 litters water for washing 10000*2/-		***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***
Service charge = 300*12		***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***
01 labour for 4,000 nut = 1,200,000/4,000 = 300 labour		***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***
Cost for pin cutter; 1 labor for 2,000 nuts (1,200,000/2,000=600 labors) @ Rs. 1,011 per head		***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***
Cost for dehydrate of coconut kernel; 1 labor for 2,000 nuts (1,200,000/2,000=600 labors) @ Rs. 1,011 per head		***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***
Cost for Kerosene oil for dryers; 24,000 liters @ Rs. 365/- per litter		***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***
Cost for crushing charges; 1,600 nuts per 1 labor (1,200,000/1,600 = 750 labors) @ Rs. 1,011/- per head		***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***

Cash Flow of Virgin Coconut Oil Production at Dodangaslanda Area Estates												
Expenditure	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11-20**
Cost for electricity; 400 units per month @ Rs. 25/-		*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*
Cost for filtering and storage; 2 labors per day (300 days) @ Rs. 1,011 per head		*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*
Cost of bottle, labeling and bottling (Rs.) ; Rs. 60/- per litter		*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*
Sales commission (Rs.) @ Rs. 50/- per litter		*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*	*2,500,000*
Transport and handling (Rs.) @ Rs. 10/- per litter		*500,000*	*500,000*	*500,000*	*500,000*	*500,000*	*500,000*	*500,000*	*500,000*	*500,000*	*500,000*	*500,000*
*Other maintenance cost; 2 labors per day @ 300 days*Rs. 1,011*		*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*
Investment	*21,731,650*											
Total expenditure (Rs.)	**21,731,650**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**	**43,989,925**
Gross margin (Rs.)	**(21,731,650)**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**	**17,385,075**
Bank Rate	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**
Discounting Factor	**1.000**	**0.862**	**0.743**	**0.641**	**0.552**	**0.476**	**0.410**	**0.354**	**0.305**	**0.263**	**0.227**	**0.051**
Discounted Cash Flow	**(21,731,650)**	**14,987,134**	**12,919,943**	**11,137,882**	**9,601,622**	**8,277,260**	**7,135,569**	**6,151,353**	**5,302,890**	**4,571,457**	**3,940,911**	**893,340**
IRR	**55%**											
NPV	**24,516,862**											
BCR	**1.29**											

Cash Flow of White Coconut Oil Production at Dodangaslanda Area Estates												
Income	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11-20**
No. of mature nuts		600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000
Oil output (Liters)												
WCO - 50% of total nuts (to produce 1 liter of WCO, needs 10 nuts)		60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Main income;												
WCO @ Rs. 950/- per litter		***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***	***57,000,000***
By products income;												
Coconut shells output (Kg) @ 8 shells per 1 Kg		75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Coconut shells income (Rs.) @ Rs. 20/- per 1 Kg		***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***	***1,500,000***
Oil cake output from WCO (Kg); Oil Cake 600000*0.350kgs = 210000Kgs *50%=105000Kgs Dry Delectated Coconut *30% = 31500Kgs Oil Cake@80/-		15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750
Oil cake income form WCO (Rs.)		***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***	***1,260,000***
Total income (Rs.)	**0**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**	**59,760,000**

Cash Flow of White Coconut Oil Production at Dodangaslanda Area Estates												
Expenditure	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11-20**
Cost of nuts @ Rs. 50.00/-		***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***	***30,000,000***
Cost for loading;												
No. loads ; 1,200,000/2,000 @ 2,000 nuts per 1 load		300	300	300	300	300	300	300	300	300	300	300
Cost; (0.5 labor per 1 load) (Rs. 1,011/- per head)		***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***
Cost for transport (1.5 T/hrs per 1 load; 650/- per 1 T/hrs)		***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***	***292,500***
Cost for de-shelling @ 2,000 nuts per labor @ Rs. 2,500/- per head		***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***	***750,000***
Cost for pairing @ 2,000 per labor @ Rs. 2,000/- per head		***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***	***600,000***
Cost for washing;												
10,000 litters water for washing 10000*2/-		***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***	***10,000***
Service charge = 300*12		***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***	***1,800***
01 labour for 4,000 nut = 1,200,000/4,000 = 300 labour		***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***	***151,650***
Cost for pin cutter; 1 labor for 2,000 nuts (1,200,000/2,000=600 labors) @ Rs. 1,011 per head		***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***
Cost for dehydrate of coconut kernel; 1 labor for 2,000 nuts (1,200,000/2,000=600 labors) @ Rs. 1,011 per head		***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***	***303,300***
Cost for Kerosene oil for dryers; 24,000 liters @ Rs. 365/- per litter		***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***	***4,380,000***
Cost for crushing charges; 1,600 nuts per 1 labor (1,200,000/1,600 = 750 labors) @ Rs. 1,011/- per head		***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***	***379,125***

Cash Flow of White Coconut Oil Production at Dodangaslanda Area Estates												
Expenditure	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11-20**
Cost for electricity; 400 units per month @ Rs. 25/-		*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*	*60,000*
Cost for filtering and storage; 2 labors per day (300 days) @ Rs. 1,011 per head		*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*
Cost of bottle, labeling and bottling (Rs.) ; Rs. 60/- per litter		*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*	*3,600,000*
Sales commission (Rs.) @ Rs. 50/- per litter		*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*	*3,000,000*
Transport and handling (Rs.) @ Rs. 10/- per litter		*600,000*	*600,000*	*600,000*	*600,000*	*600,000*	*600,000*	*600,000*	*600,000*	*600,000*	*600,000*	*600,000*
*Other maintenance cost; 2 labors per day @ 300 days*Rs. 1,011*		*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*	*303,300*
Investment	*21,731,650*											
Total expenditure (Rs.)	**21,731,650**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**	**45,189,925**
Gross margin (Rs.)	**(21,731,650)**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**	**14,570,075**
Bank Rate	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**
Discounting Factor	**1.000**	**0.862**	**0.743**	**0.641**	**0.552**	**0.476**	**0.410**	**0.354**	**0.305**	**0.263**	**0.227**	**0.051**
Discounted Cash Flow	**(21,731,650)**	**12,560,409**	**10,827,939**	**9,334,430**	**8,046,923**	**6,937,002**	**5,980,174**	**5,155,323**	**4,444,244**	**3,831,245**	**3,302,797**	**748,690**
IRR	**44%**											
NPV	**17,513,632**											
BCR	**1.22**											

Cash Flow - Coconut Soft Ice Cream Production							
Income	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Income from Ice Cream Cones							
Cone Production/Year (Rs.)		1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	
Price per cone (Rs.)		65	65	65	65	65	
Income from Ice Cream Cones/Year (Rs.)		**65,000,000**	**65,000,000**	**65,000,000**	**65,000,000**	**65,000,000**	
Income from Byproducts							
Income from coconut shell		3,500,000	3,500,000	3,500,000	3,500,000	3,500,000	
Income from coconut oil;		1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	
Income from poonak;		486,000	486,000	486,000	486,000	486,000	
Income from Byproducts/Year (Rs.)		**5,426,000**	**5,426,000**	**5,426,000**	**5,426,000**	**5,426,000**	
Total Income/Year (Rs.)		**70,426,000**	**70,426,000**	**70,426,000**	**70,426,000**	**70,426,000**	
Expenditure	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
1) 100,000 coconuts nuts @ Rs. 80/-		8,000,000	8,000,000	8,000,000	8,000,000	8,000,000	
2)		7,370,000	7,370,000	7,370,000	7,370,000	7,370,000	
3		120,000	120,000	120,000	120,000	120,000	
4		160,000	160,000	160,000	160,000	160,000	
5		232,000	232,000	232,000	232,000	232,000	
6 Ingredients		320,000	320,000	320,000	320,000	320,000	
7		640,000	640,000	640,000	640,000	640,000	
8		1,318,600	1,318,600	1,318,600	1,318,600	1,318,600	
9		868,000	868,000	868,000	868,000	868,000	
10		29,000.00	29,000.00	29,000.00	29,000.00	29,000.00	
Ice cream cones		6,000,000	6,000,000	6,000,000	6,000,000	6,000,000	
Electicity cost		2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	
Other		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	
Labour cost		10,800,000	10,800,000	10,800,000	10,800,000	10,800,000	
Tax Expenses		0	8,124,478	5,687,135	6,418,338	6,198,977	6,726,035
Investment	16,150,000						
Total Expenditure/Year (Rs.)	**16,150,000**	**40,257,600**	**48,382,078**	**45,944,735**	**46,675,938**	**46,456,577**	**6,726,035**
Gross Margin (Rs.)	**-16,150,000**	**30,168,400**	**22,043,922**	**24,481,265**	**23,750,062**	**23,969,423**	**-6,726,035**
Bank Rate	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**1.16**
Discounting Factor	**1.00**	**0.86**	**0.74**	**0.64**	**0.55**	**0.48**	**0.01**
Discounted Cash Flow	**(16,150,000)**	**26,007,241**	**16,382,225**	**15,684,110**	**13,116,948**	**11,412,154**	**(66,227)**
IRR	**132%**						
NPV	**35,468,543**						
BCR	**1.40**						