COCONUT BASED INTEGRATED FARMING SYSTEM

(MANAGE Off-Campus Training Programme)

Training Manual

Editors

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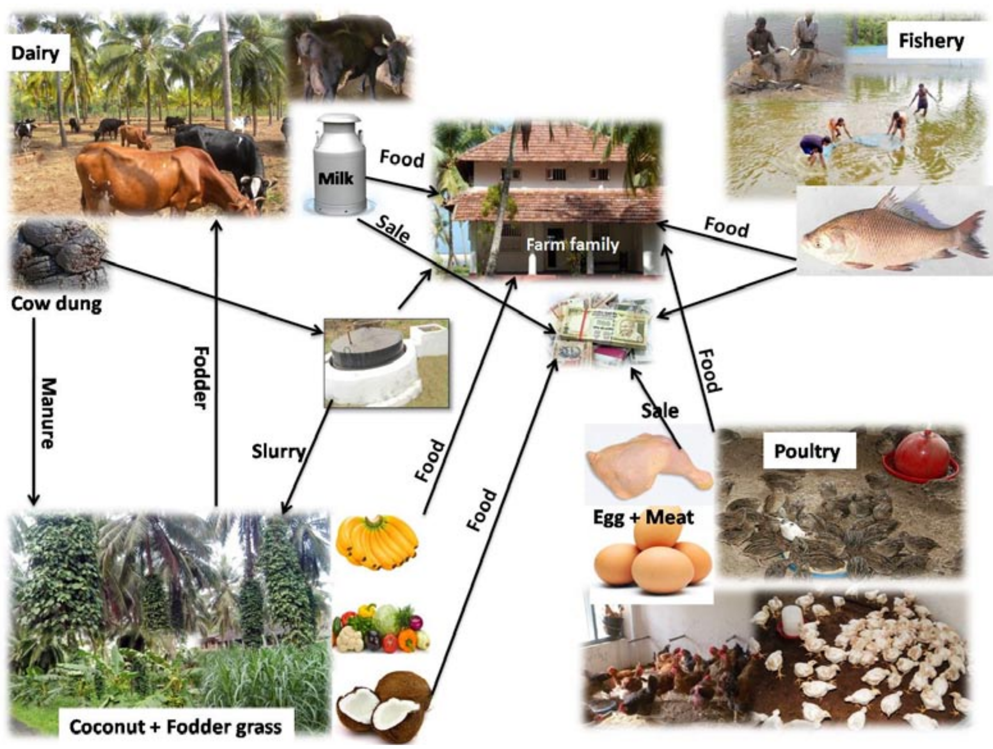

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CONTENT

Feasibility of Coconut Based Cropping System: Scope and Concept

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Introduction

Coconut (*Cocos nucifera* L.) is a perennial palm popularly referred as "*Kalpavriksha*", "*Tree of Heaven*", "*Tree of life*" or "*Nature's supermarket*". The innumerable benefit it provides to millions of people has made it nature's gift to the mankind. The crop is mainly cultivated in tropical and subtropical climate and it is the most important palm among the palms cultivated and utilized in the world. Coconut is committed to the land for many years and the palms start giving returns only after 5 to 7 years. Coconut is mostly a crop of small farmers in India, the average size of a holding being 0.22 ha. More than 90% of the five million coconut holdings in the country are less than one ha in size. Due to the problems like long pre-bearing period, occurrence of pests and diseases and fluctuating market prices apart from the small size of holdings, the crop has failed to generate sufficient income to sustain even the small families. The farm yields under mono cropping system in traditional coconut growing states in India, are poor and farmers are under employed spending only 100 and 120 man-days, under rainfed and irrigated systems of cultivation, respectively. Thus diversifying the cropping system including more crops per unit area may be necessary to sustain the small and marginal coconut farm families.

Feasibility of cropping system in coconut

The recommended spacing for coconut is 7.5 m X 7.5 m, which is based on the canopy cover of the palm over years. At this spacing the crop fails to utilize the two of the basic natural resources viz., soil and solar energy efficiently. Studies have revealed that planting method and growth habit of sole coconut palms spaced at 7.5 m x 7.5 m use only 22.3% of land area effectively while the average air space utilization by the canopy is about 30% and solar radiation interception is 45-50%. However, the effective root zone of the adult palm is confined laterally within a radius of 2 m around the base of the palm and over 95% of the roots are found in the top 0-120 cm, of which 18.9 and 63 % of roots are confined to top 0-30 cm and 31-90 cm depth, respectively. Making use of the underutilized soil space and solar radiation in pure stands, a variety of crops having different stature, canopy shape and size and rooting habit can be inter planted to form compatible combinations. Such intercropped plantations will intercept and utilize light at different storey's and forage soil at different strata maximizing biomass production per unit area of land, time and inputs.

Increasing productivity and income

The income derived from most of the coconut holdings is insufficient to sustain the dependent families as most of coconut holdings are small holding i.e. < 0.2 ha. Growing compatible annual and perennial intercrops in such coconut holdings is a promising way of increasing productivity and generating more income and employment opportunities. In addition to that price fluctuation of coconut also necessitates the importance of growing intercrops. Coconut based intercropping systems increase the productivity of the system as a whole and thereby increases the net returns from the system. It is recommended to go for low volume high value crops as intercrops in coconut garden.

Factors influencing cropping system

Age of the plantation

The life span of coconut palm could be a divided into 3 distinct phases.

*a. Planting till full development of canopy (about 5- 8 years):*A major portion of the solar energy is not being intercepted by coconut leaves, good transmission initially, as the palm canopy develops with age, the percentage of utilization increases progressively during the pre-bearing period, with a corresponding decrease in transmission of light. The suitable crops are cereals, grain legumes, vegetables, spice crops, flower crops, fruit crops like banana, pineapple etc.

b. Young palms (8 to 20 years): The period from 8 to 25 years is the second phase when the coverage of ground canopy is about 80% and there is little scope for intercropping. However, the crops which can sustain more shade can be grown as intercrop during this period

c. Adult palms (more than 20 years): Increase in trunk height; reduction in crown size - light transmission increasing with age (high light levels) - the amount of slant rays of sun falling on the ground increases and consequently, the apparent coverage of ground by the canopy of coconut decreases progressively. Ideal for raising annual and / or perennial crops as multiple and multistoried cropping models.

Choice of crops

The selection of crop for intercropping depends on the soil type, rainfall pattern, and availability of irrigation, local demand and the ability of the crops to withstand shade. Further the crops should not compete with the main crop for nutrient and water. The crops should not have common disease and pests problems.

Spatial arrangements

When two or more crops are grown together, each must have adequate space to maximize cooperation and minimize competition between them. To accomplish this, proper attention should be given to spatial arrangement, plant density, and plant architecture. The intercrops when grown in the interspaces of coconut, a circular area of about 2 m radius around the palm is left free and the intercrops are grown in the interspaces of coconut rows as per recommended method of planting.

Management of crops

The success of the cropping system depends on how it is managed. The competition between the crops should be minimum in the system. The nutrient and water requirement of the intercrops should be taken care along with the main crop. The planting of the intercrops should be taken up leaving 2.0 m radius around the palms to avoid competition among the crops. The sandy soils which have very low moisture and nutrient holding capacity where coconut is a major crop, intercropping can be made possible by adopting appropriate technologies developed at ICAR-CPCRI viz., husk burial, leaf burial etc.

Conclusion

In coconut farming, with or without higher price of nut or copra, the coconut based cropping systems guided by the modern and productive concept and application of basic principles involved, the social, environmental and economic or monetary benefits are substantially enhanced and become highly attractive to coconut farmers.

Coconut based multiple cropping – Concepts, models and impact

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Introduction

Very often, intensive agricultural systems aim to optimize the productivity of monocultures. The crop diversity, in such mono cropping systems, is reduced to one or very few species that are generally genetically homogeneous. The planting pattern is uniform and symmetrical, and they extensively use external inputs. Such systems are widely criticized today for their negative environmental impacts, such as soil erosion and degradation, chemical contamination, loss of biodiversity, and over dependence of fossil fuel etc.

Growers of plantation tree crops are not able to revise their land use decisions on a year-to-year basis and they are, therefore, particularly exposed to risks of environmental and market shocks, including sudden price fluctuations of international commodity markets, as well as changing government policies. Under such situations, crop diversification allows farmers to gradually adapt to a changing environment (progressive decline in soil fertility, build-up of weeds, pests and diseases, climate change etc.) through a systematically planned transition process from one dominant crop to another.

In comparison to monoculture, multispecies cropping systems could be considered as a practical application of ecological principles based on biodiversity, plant interactions and other natural regulation mechanisms. They have the potential advantages in productivity, stability of outputs, resilience to disruption and ecological sustainability etc. A majority of the world's farmers, particularly those located in tropical regions, still depend for their food and income on multispecies agricultural systems, which consist of growing several crops simultaneously in the same field, or mixing several plant species within the same field: field crop species, forage crop species, trees, or combinations of all these. The economic profitability of multispecies systems relates to their productivity and when coconut plantations are established, crop mixing enables to generate additional income in the first years of the plantation, when the palms are still unproductive, do not produce any economic returns and also occupy a confined field space.

Coconut is one of the important plantation crops of India having the status of a high value commercial crop with an annual production of 22,167.45 million nuts from an area of 20.88 lakh ha (CDB Statistics-2015-16. Predominantly coconut is a small farmer's crop, the average size of holding being 0.22 ha. Quite often, the income derived from such small holdings will not be adequate enough to make both ends meet in case of small families. In traditional coconut growing regions of India, with mono cropping, the total productivity is comparatively low and the employment potential of farmers is underutilized. The resource use efficiency is also quite low resulting in farm production and productivity to be not sustainable. However, coconut gardens offer excellent opportunities to exploit the inter-space potential for very effective use of natural resources as well as maximizing returns per unit area (Fig.1). Mixed/multiple cropping of coconut gardens with food crops is generally the most economical way of caring for the young palms as long as the seedlings do not fully occupy the site. It also increases food security during the first years before the palms come into production and generate cash revenue.

Fig.1 Mono crop of coconut: Note the availability of inter space and solar radiation for crop diversification

Coconut Based Multiple Cropping

Coconut based multiple cropping aims at crop diversification and intensive cultivation of crops in the inter space available in coconut gardens to increase per palm as well as unit holding productivity in a system approach. Such a system enables the use of available farm resources like soil and water/rainfall, farm labour, agricultural inputs (seeds, fertilizers, agro-chemicals) etc. to produce nuts, food and non-food agricultural products from the farm, in a business or profitable way. Sustainability is the main objectivity of farming system, where production process is optimized through efficient utilization of the inputs in safeguarding the environment.

Suitability of Coconuts for Multiple Cropping

The main characteristics that determine the suitability of coconut (a tall unbranched palm, with a terminal crown of leaves, growing to a height of 20–30 m, with a life span of 80–100 years) for multiple cropping are:

1. *The planting distance:* Generally in the range of 7 m × 7 m to 10 m × 10 m for tall cultivars, (with an average planting density of around 130–180 palms ha^{-1}, depending on whether rectangular, square or triangular planting systems are used) and in coconut monoculture as little as 25 per cent of the land only will be effectively used (providing a very low utilization efficiency of agricultural land) and leaving the remaining for introducing other crops.
2. *The morphological features of the coconut* (single stem with leaves well oriented to all directions): the palms occupy only less than 30–40 per cent of the available air space between canopy and ground during the major part of their life span.
3. *The nature of the canopy of fronds:* The well oriented fronds intercept incoming solar radiation and on an average, around fifty six percent of solar radiation will be reaching the ground and becoming available for intercrops, although this will vary with age of the coconut palms and planting density.
4. *The rooting pattern of the roots:* The coconut roots are mostly in the 30–120 cm soil layer in a 2 m radius around the palm, thus, leaving some seventy to seventy five per cent of the soil unutilized or underutilized.

Relevance of Coconut Based Multiple Cropping

The main relevance of coconut based multiple cropping are: Income stability, Social and ecological benefits, conservation of natural resources, biodiversity conservation, supply of biomass and employment generation.

1. *Income stability:* Stability has often been presented as the main reason for adopting multispecies cropping systems in situations exposed to risk, such as poor tropical agriculture. Multispecies systems that provide several products can maintain a more stable income, particularly if price variations for those products are not correlated. Multispecies systems can also offer ample scope for biomass recycling and thereby reduce requirement of external fertiliser and pesticide inputs. Such lower dependence on external inputs makes multispecies systems more resilient to external changes, such as product prices.

2. *Social benefits:* Social benefits relate to the food and nutritional functions of coconuts as well as various crops grown under the system. Growing of intercrops in coconut lands produces more food and agricultural products, ensuring food security of the people in rural and urban areas.

3. *Ecological benefits:* Compared to the ecological conditions of the long-term mono culturing, those of lands put to multiple cropping are more favourable and stable for intensive and sustainable agricultural production. This is mainly because of the more efficient utilization of various natural resources, higher biomass generation and recycling over a period of time.

4. *Conservation of natural resources:* The land cover minimizes the direct impact of rainfall and the separation of soil aggregates under coconut environment, which can control surface runoff and soil erosion by 70 to 90 per cent, compared to bare soil or un-cropped condition. An adequate ground cover can also increase rainwater infiltration and storage, eventually increasing water supply of the entire area. Because of the shade under coconut stand and full canopy coverage, evaporative demand is very much reduced and intercropping allows a better retention of water in the soil for a longer period. The microclimate in the coconut garden maintains not only lower air temperatures (by 4–6°C beneath the canopy but also lower soil temperatures.

5. *Biodiversity conservation*: Due to the uniqueness in the growth pattern, coconut offers scope for accommodation of many crop species for inter/mixed cropping, which in turn helps plant genetic resources conservation and management. The coconut based multiple cropping favours diversity in the soil microflora as well. Cultivating crops with different time of planting and maturity period provides opportunities to the farmer to plant and harvest crops at multiple points in the season to guard against total crop loss to environmental risks, price fluctuations as well as earn year-round income. Cultivation of coconut along the coastal belts has known to save the hinterland from cyclonic storms by absorbing the destructive forces of the wind and water and acting as a bio-shield. The non-uprooting of coconut palms along the seacoast during the tsunami is a testimony to the service of coconut to the mankind.

6. *Diversity of Soil Organisms:* Soil organisms are an inseparable part of agricultural ecosystems. The presence of diverse community of soil organisms is very much needed for the maintenance of healthy and productive soils. Soil organisms are responsible for a large

number of ecological functions and ecosystem services including: nutrient cycling and N_2-fixation, P-solubilization, decomposition of organic matter as well as carbon sequestration, maintenance of a good soil structure for plant growth and rainwater infiltration, detoxification of contaminants, control of pest and diseases(as bio control agents), etc. Coconut rhizosphere harbours a wide range of beneficial microorganisms which take part in improving the nutrient and fertility status of coconut gardens. The belowground microbial diversity (general as well as function specific) is found to be higher in multiple cropped coconut gardens, than mono-cropped ones, and is greatly influenced by the type of above ground vegetation such as annuals biennials and perennials. Hence, the functioning of the below ground microbial communities greatly influences the stand of the above ground vegetation and both are highly interrelated. This, apart from crop diversity, also forms an important ecosystem service provided by the coconut based cropping systems.

7. *Nutrient recycling:* Coconut Based Multiple Cropping enables production of large quantities of biomass which could be effectively recycled and put back in to the system for soil fertility improvement. Such system will also enable nutrient mining from deeper soil layers by coexisting species exploring different soil depths. This increases nutrient-use efficiency and reduces nutrient leaching from the soil layers explored by the crops.

8. *Soil conservation and water quality*: The vast and diverse nature of coconut root system offers its role on soil conservation and subsequent leaching of nutrients. Adventitious roots, typical of monocot plants are produced from the base of coconut stem throughout its life. Around 4000 to 6000 roots are produced from the bole region, which again produces branch roots and tertiary rootlets. The can grow to a distance of 6 m to 25 m. This type of root system in coconut facilitates the creation of good soil structure and improves soil aeration and drainage. The enhanced root activity can also improve the microbial activity. The root exudates from coconut can neutralize soil pH, alter the microclimate of rhizosphere, promote soil aggregation and increase nutrient exchange capacity of soil. Multispecies cropping systems will increase soil cover, root presence in the topsoil and obstacles to run-off on the soil surface, hence decreasing soil erosion, having a positive impact, on a watershed scale, on the water quality of rivers, and on the intensity of floods.

9. *Carbon sequestration:* Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation and geologic formations. When more photosynthesis takes place, more CO_2 gets converted into biomass, thereby reducing carbon in the atmosphere and sequestering it in plant tissue as above and below ground biomass. Soil carbon plays a very important role in improving plant health, ability to make available nutrients to plants through microbial intervention, increasing water-holding capacity, maintaining biodiversity etc. For the carbon sequestration, the measurement of the net annual CO_2 fixed in the coconut trunks and roots will reflect the capability of the plant to transform atmospheric carbon into biomass in the tissues of coconut. In the case of coconut, the annual carbon sequestration in the above ground biomass is reported to vary from 15 to 35 Mg CO_2/ha/year depending on cultivar, agroclimatic zone, soil type and management. Assuming that the fronds, husk, shell and peduncle are used as fuel, the net CO_2 fixed by coconut in the roots and trunk is estimated by coconut researchers to be 12.81 Mg CO_2/ha/year. Different coconut types have different growth rate, and hence, they differ in the amount of carbon sequestered. Multispecies

cropping systems can sequester carbon over pure crop stands. Trees and/or cover crops also enhance the soil carbon content, thus participating in climate change mitigation.

10. *Employment generation from farm diversification:* Since various crops with different growth pattern and duration are included in the multispecies cropping systems, their cultivation coupled with value addition, provides opportunities for more employment generation.

11. *Other services:* Multispecies cropping systems can also provide other services, linked to the quality of the environment: trees over crops can provide shade and shelter for animals and humans, and, on a landscape scale, enhance the aesthetical value of land. However, such services are difficult to assess.

Coconut Based Mixed Cropping

Growing of perennial crops with adult coconut palms is referred to as mixed cropping. A number of perennials like cocoa, clove, nutmeg, coffee, black pepper, mulberry, clove, cinnamon, mango, sapota, papaya, coffee, cardamom and other crops can be successfully grown with coconut. Mixed cropping coconut with perennials is popular in large-scale plantations. Perennials are particularly suited for mixed cropping with coconut because once they reach maturity they continue to provide a steady flow of income with limited maintenance requirements. This is also considered important under smallholder production systems where resources are limited. Coffee is a popular mixed crop under mature coconut stands. The shade from coconut palms provides optimum conditions for coffee's growth and productivity. The profitability of growing cacao as mixed crop in coconut has been established in field experiments. In Kerala, India, coconut intercropped with double rows of cacao was more profitable than that intercropped in a single row. Representation of various cropping models (Fig.2 to Fig.6) is presented below (Paul, C., and E. Ramkhelawan. 2016. Coconut Intercropping Systems. International Trade Centre, Geneva, Switzerland)p.24.

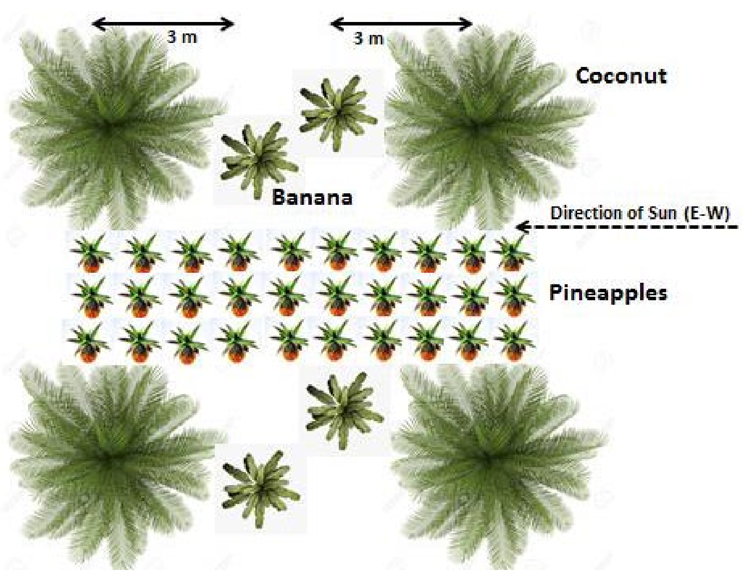

Fig.2 Representation of multiple cropping systems of pineapple + banana + coconut. Distances between crops are arranged so that roots do not overlap

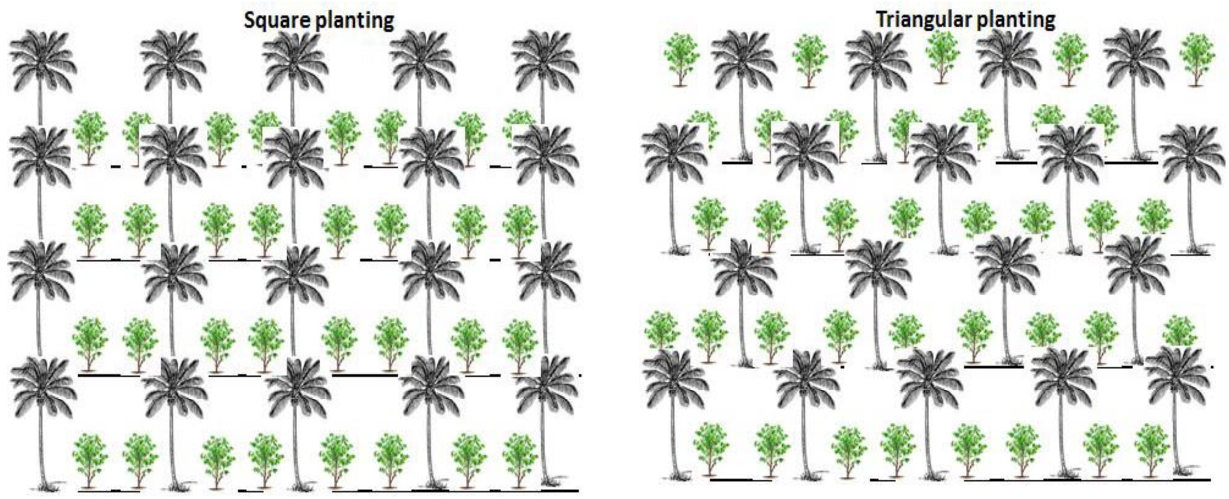

Fig.3 Representation of Coconut + cocoa cropping model [square planting (left) and triangular planting system (right)]

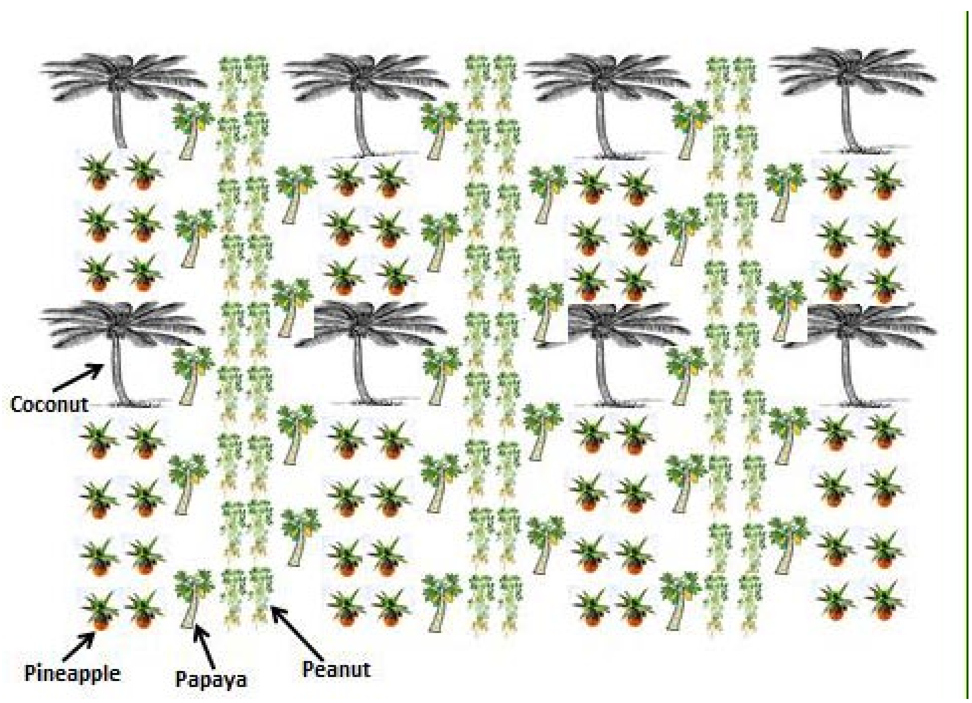

Fig.4 Field arrangement of mixed cropping model for coconut + pineapple + papaya + peanut cropping system

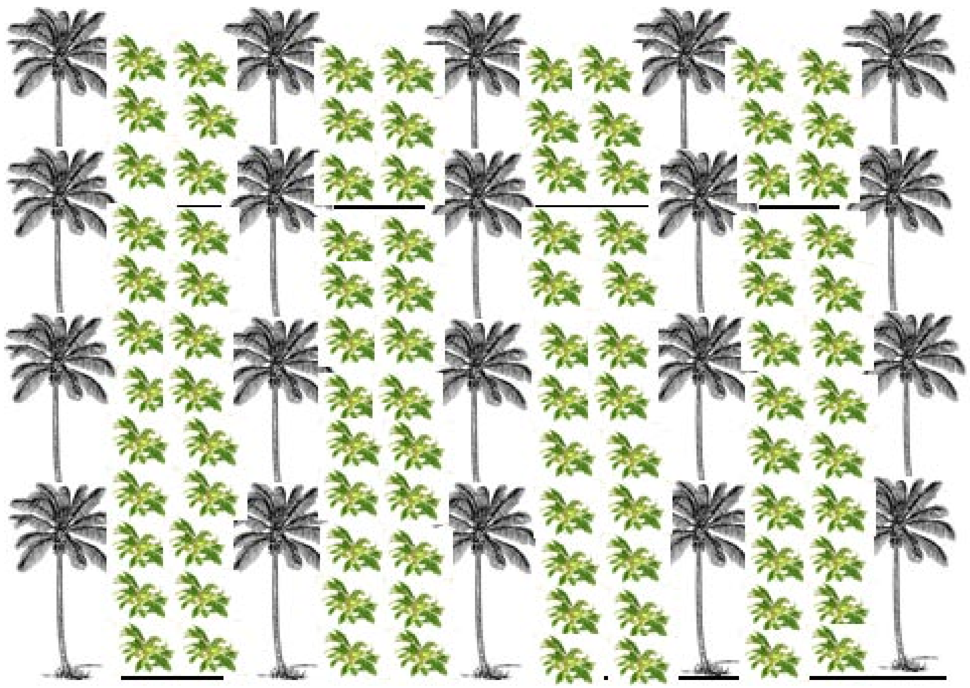

Fig.5 Representation of Coconut + root crop multiple cropping model

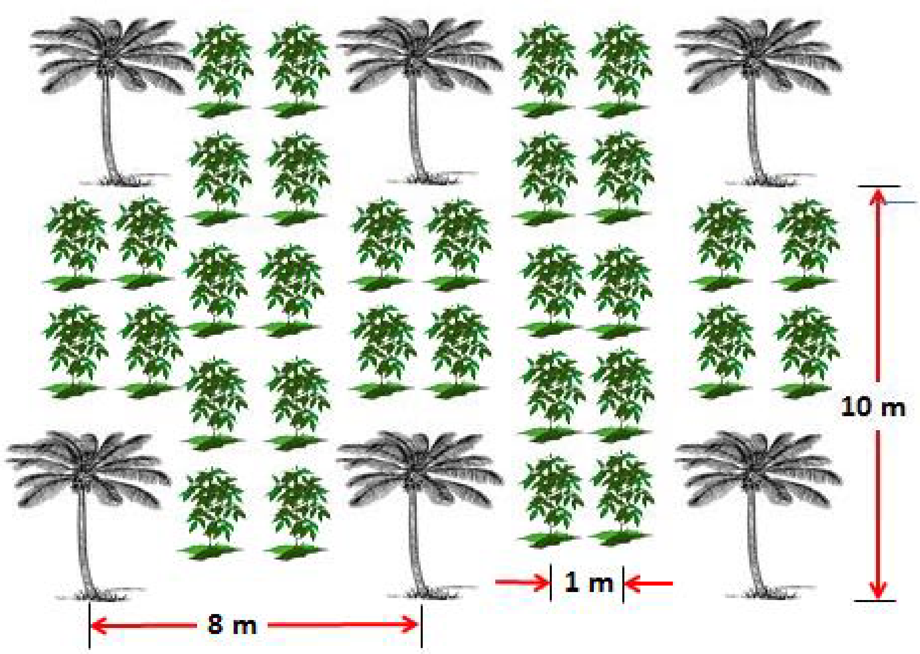

Fig.6 Representation of Coconut + coffee multiple cropping system

High Density Multispecies Cropping

High Density Multispecies Cropping System (HDMCS) or Multistoried cropping system involves growing coconut and a combination of annual and perennial crops of different heights, rooting characteristics and canopy patterns in the same garden (between coconuts) so as to maximize utilization of solar radiation, nutrients and moisture(Fig.7). This system requires more management skills, labour and other inputs than most other systems. Diversifying the farming system by intercropping cash crops, such as cacao, coffee, banana, pineapple etc. and changing to multi-storied cropping systems, can generate much higher returns. Crops having varying canopy heights are selected in this intensive cropping system with the objective of greater utilization of solar energy and soil resources.

Fig.7 Coconut based high density multispecies cropping: Note: The crops are coconut, black pepper, cocoa, banana, colocasia, ginger occupying different heights in the plantation

Understanding farmers' objectives, preferences, and constraints can help in devising strategies and policies to support their diversification decisions. The following components are of particular importance in such strategies.

1. The farmers need information about technical and marketing options of alternative crops, as well as risks involved, so that they can make informed choices.

2. The farmers are very often constrained by a lack of capital to invest in alternative crops. Therefore, the availability of affordable credit is important, but it must amply be supported by technical and marketing assistance to avoid they becoming indebted when their investments fail.

3. Since marketing is such a critical factor in the success of a new crop, care must be taken that marketing channels are reliable and that there is preferably a range of marketing options. There should be possibility of value addition, in case the surplus production could not be marketed immediately after harvest (this is more applicable for perishable commodities such as fruits and vegetables).

4. Since small farmers are typically labor-constrained, diversification options whose labor requirements are complementary to those of the existing crops, (rather than increasing total labor needs during phases of peak demands), are preferable as they do not proportionally increase the dependence on hired labor that may be expensive or unavailable. Efficient use of farm family labour would be advisable.

5. Improved planting materials should be made available to ensure that newly established crops are productive, pest- and disease tolerant, and their products are of good quality.

The processes and properties in coconut based multispecies cropping system is depicted in Fig.8.

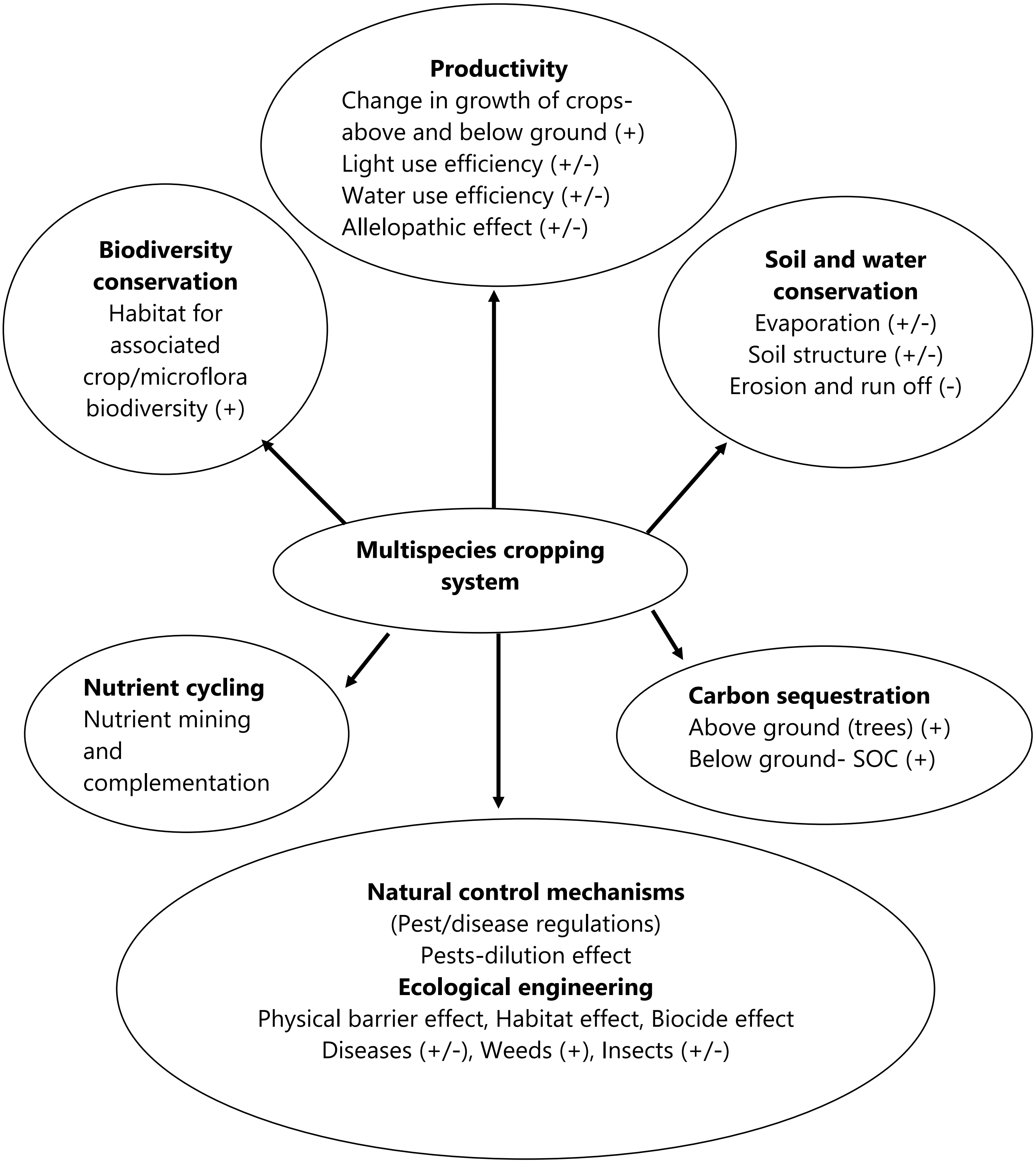

Fig.8 Processes and properties in coconut based multiple cropping

Coconut based mixed farming system-concepts, models and impact

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Introduction

Coconut is predominantly cultivated in small and marginal holdings in India and the major coconut growing state are viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. About 98 per cent of the coconut holdings in the country are less than two ha in area and more than 90 per cent of them are less than one hectare in extent. Most of these holdings neither provide gainful employment for the family labour in a year nor generate sufficient income to satisfy the family requirement. Coconut palm when grown as a monocrop, does not fully utilize the resources *viz.,* soil, nutrients, moisture and solar radiation available in the garden. There is ample scope to exploit these resources for the integration of crops and animals in coconut garden for enhancing income and employment opportunities. Presently coconut growers are exposed to economic risks and uncertainties owing to the frequent price fluctuations for the produce. In this context it is needless to emphasize the importance of crop/enterprise diversification in coconut gardens.

Integrated Farming is a common whole farm management approach that combines the ecological care of a diverse and healthy environment with the economic demands of agriculture to ensure a continuing supply of wholesome, affordable food. Coconut based cropping/farming systems, involving cultivation of compatible crops in the interspaces of coconut and integration with other enterprises like dairying, poultry and aquaculture offer considerable scope for increasing production and enhancing productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour. Majority of the coconut growing soils are poor in soil fertility and needs external inputs ,coconut based farming is one of the optional to enhance productivity. 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.

Agronomic feasibility of coconut based mixed farming system

A spacing of 7.5 m x 7.5 m is recommended for planting coconut in the square system. Experimental evidences have shown that a sole crop of coconut, at the recommended spacing of 7.5m x 7.5 m does not fully utilize the available resources such as land space, aerial space, water and nutrients.

a. Rooting pattern

Coconut palm like all monocots has a typical adventitious root system. Under favourable conditions, as many as 4000 to 7000 roots are found in the middle-aged palms. About 74 per cent of the roots produced by a palm under good management do not go beyond 2 m lateral distance and 82 per cent of the roots were confined to the 31 to 120 cm depth of soil. Recent studies have confirmed that more than 80 per cent of the root activity was confined to a lateral distance of 2 m from the trunk (Fig.1). Thus in a coconut garden the active root zone of coconut is confined to 25 per cent of the available land area and the remaining area could be profitably exploited for raising subsidiary crops.

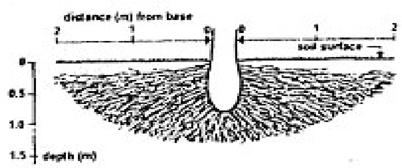


Fig. 1. Schematic presentation of the rooting spread pattern of an adult coconut palm.

b. Canopy structure and light utilization

The venetian structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The leaves in a coconut palm crown are not randomly distributed, but clumped around few widely spaced growing points. It is estimated that as much as 56 per cent of the sunlight is transmitted through the canopy during the peak hours (10-16 hours) in palms aged around 25 years. The diffused sunlight facilitates growing a number of shade tolerant crops in the interspaces. Thus canopy structure and light utilization pattern render coconut palm as the tree crop most suited to integration.

In general, fodder can be grown as intercrop throughout the life cycle of coconut palm. However, more fodder yield is realized under first part (up to 8 years) and third part (above 20 years) of the coconut life cycle.

Components of the typical Coconut based integrated farming system

The components of a typical coconut based integrated farming system in one ha area under study at ICAR-CPCRI are furnished in Table 1 below.

Table 1. Components of coconut based integrated farming system

Sl. No.	Component	Area (ha)/ numbers
1	Coconut (WCT))	175 nos.
2	Fodder grass(BN Co 3) and guinea grass/ Fodder sorghum, fodder maize, (Stylosanthus- annual and perennial), fodder cowpea	1.00 ha
3	Pepper (Panniyur 1) planted in coconut basin and trailed on the coconut stem	175 nos.
4	Banana (Kadali a local variety) planted on border areas	195 nos.
5	Dairy (Holstein Friesian and Jersey cross breed cows) – 8 nos.	0.02 ha.
6	Poultry (100 broiler birds / batch, 4-6 batches per year)	
7	Biogas plant (3 m^3) – 1 no.	
8	Azolla unit (4 m^2) – 3 nos.	
9	Goat unit (20 does and two bucks)	
10	Aquaculture (Catla, Rohu, Mrigal, Grass carp) - 1000 fingerlings in the pond of 27.5 x 22.5 x1.5 m	0.062ha

. includes space occupied by the pump house and farm house

Management of component crops and enterprises

Crop components

a) Coconut

Coconut palms were planted in a spacing of 7.5 m x 7.5 m and the crop is maintained by proper integration with other components in the system and the age of garden is 40 years. Cow dung, biogas slurry, cow shed washings, poultry manure and recycled water from fish pond were utilised in the coconut garden.

Since grass was inter planted in the coconut garden, irrigation at the rate of 20 mm once in 4 days was practiced through sprinkler irrigation, which is equivalent to 100 per cent of open pan evaporation. This works out to be 2,00,000 litres per irrigation per ha. Other regular cultural practices were adopted as per the package of practices. About 3.45 tonnes of coconut leaves were obtained from the system per annum which was recycled in to the system by vermicomposting and mulching and initially 70 % recovery is obtained and left over partially decomposed materials are also decomposed subsequent composting process.

b) Banana

In order to utilise the available land resource effectively and generate more income from the system banana was chosen as a component crop and it was planted around the periphery of the coconut garden. In one hectare area of coconut plantation approximately 300 bananas were planted with an interval of 2 m in single row system (Fig.2.). Cultural practices were adopted as per the package of practices. From this crop component, 728 kg of biomass on dry weight basis was produced per annum, which was recycled in to the system.

Fig. 2 : Banana along the border

Fig.3: Pepper vines trailed on coconut palm

c) Pepper

Pepper (variety Panniyur-1) was planted in coconut basin and trailed on the coconut. Nutrient management practices were implemented as per treatment requirements as detailed above. Other cultural practices were adopted as per the package of practices (Fig.3).

d) Fodder grass

Intercropping of fodder grass in the interspaces of coconut is one of the components of the coconut based integrated mixed farming system. The selected grass should have the following desirable characters viz.

- Low competition with coconut for resources such as plant nutrients and soil moisture
- Ability to withstand shade
- Good response to fertilizer application
- Compatibility to grow with leguminous fodder plants
- Relished by cattle.

The studies conducted at ICAR-CPCRI, Kasaragod have shown that various pasture grasses (*Brachiaria miliiformis*, *B. brizantha*, *B. ruziziensis*, *B. mutica*, *B. dicotyoneura, and Digitaria decumbens),* fodder grass varieties (Guinea grass (*Panicum maximum*), Hybrid Napier: NB 21 and BH-18, Hybrid Bajra Napier (Co 2), Guatemala grass (*Tripsacum laxum*), Blue panic (*Panicum antidotale*), Rhodes (*Chloris gayana*), Sudan grass (*Sorghum sudanense*), leguminous fodder species viz., Brazilian lucerne (*Stylosanthes gracilis*), Cowpea (*Vigna unguiculata*), Centro (*Centrosema pubescens*) and Pueraria (*Pueraria javanica*) and grass + legume mixture species (Hybrid Napier + *Stylosanthes gracilis*), Hybrid Napier + *Pueraria javanica* and Hybrid Napier + *Centrosema pubescens* could be successfully cultivated in coconut garden.

The details of management and performance of these fodder crops are presented as follows.

i) Hybrid Bajra Napier Co 3 fodder grass

This grass has long and broad leaves with very little stem portion (leaf to stem ratio is 0.7) making it highly palatable. Under rainfed conditions, the best season of planting is with the onset of southwest monsoon during May-June. As an irrigated crop, planting can be done at any time of the year. The grass is planted by rooted slips or by stem cuttings. Cuttings of moderately mature stems (3 months old) and preferably from the lower two thirds of the stem length sprout better than the older stems. The cuttings are planted in a slanting position with the spacing of 60 cm x 60 cm. The cuttings with three nodes are put into the soil with the basal end down taking care that two nodes remain within the soil and one node above the soil surface. The underground nodes develop roots and shoots while the upper ones develop shoots only. Planting during heavy rainfall period should be avoided. The field should be provided with good drainage during the rainy season, as the crop cannot withstand water stagnation. Sprinkler system of irrigation with 20 mm of water at IW/CPE ratio of 1.00 is to be adopted and around 200000 liters water is required for one irrigation and the interval will be once in four days. Frequency of irrigation depends upon the rainfall and weather conditions. Intercultivation once or twice is necessary to avoid weed growth in the initial period for better establishment and vigorous growth (Fig. 4). Subsequently, intercultivation should be given as and when necessary. First cutting of the grass should be done at 80 days after planting. Subsequently the grass is cut once in 45 days. Cutting should be done close to the ground level leaving stubbles of 5- 10 cm height. It has got quick regeneration capacity also. The grass can be maintained for a period of three years. Replanting should be done after three years. Leguminous green manure crops can be raised in the interspace and can be incorporated before replanting of grass.

The study has indicated that application of organic manures recycled from the system along with chemical fertilizer resulted in highest yield of grass (117 t/ha/year). The Crude protein content ranges from 11.94 to 12.69. It was interesting to note that crude protein content was higher when the fodder grass was grown as intercrop when compared to monocrop. This is mainly due to the nitrogen content of grass was higher under shaded conditions. This quantity of fodder is sufficient to maintain 10-12 milching animals.

Staggered planting of fodder grass is recommended depending on the number of cattle to be fed to avoid wastage of fodder grass. Based on the experimental results at CPCRI, Kasaragod the recommended pattern of staggered planting of fodder grass to meet the requirement of cattle as part of CBIFS is furnished in Table 2.

Table 2. Recommended pattern of staggered planting of fodder grass

No. of milch animal	Area in cents	Area of staggered planting in cents					
		Days of planting in the first month					Day of planting in the second month
		1st	7 th	14 th	21 st	28 th	5 th
1	24-25	4.2	4.2	4.2	4.2	4.2	4.2
2	48-50	8.3	8.3	8.3	8.3	8.3	8.3
3	72-75	12.5	12.5	12.5	12.5	12.5	12.5
4	96-100	16.6	16.6	16.6	16.6	16.6	16.6
5	120-125	20.8	20.8	20.8	20.8	20.8	20.8
6	144-150	25	25	25	25	25	25
7	168-175	29.2	29.2	29.2	29.2	29.2	29.2
8	192-200	33.3	33.3	33.3	33.3	33.3	33.3
9	216-225	37.5	37.5	37.5	37.5	37.5	37.5
10	240-250	41.6	41.6	41.6	41.6	41.6	41.6

ii) Guinea grass

Guinea grass is an important perennial bunch fodder grass species of the tropics. It is an excellent fodder, much valued for its high productivity, palatability and good persistence. This grass tolerates shade and grows under trees and bushes and is best suited as an intercrop in coconut gardens. It can perform well under rainfed conditions also. The grass is adapted to a wide range of soil conditions. It usually grows on well-drained light textured soil, preferably sandy loam or loam and is better suited to medium to highly fertile loam. The field should be ploughed two to three times to obtain a good tilth before planting. The best season of planting is at the onset of southwest monsoon during May-June. Under irrigated conditions, planting can be done at any time of the year. Since seed germination is poor, vegetative propagation is preferred. To obtain slips for planting, old clumps are uprooted and slips with roots are separated. The spacing of 50 x 50 cm is followed and the crop is planted in trenches of 30 cm width and depth. A basal dose of 10 to 20 tonnes of FYM, 50 kg P_2O_5 and 50 kg K_2O per ha (applied in trenches) is recommended. 25 kg of nitrogen/ha should be applied after each cut. Under rainfed conditions fertilizer should be applied only when there is sufficient moisture in the field. Sprinkler system of irrigation is ideal with 20 mm of water at IW/CPE ratio of 0.75. Cowshed washing from the dairy unit and water from fish pond can also be used for irrigation especially during the initial stage for better performance of the grass. Cutting at 10 cm above the ground level is advised. The first cut is usually ready in 9-10 weeks after planting and subsequent cuts are taken at 45 to 60 days intervals. About six to seven harvests can be made in a year. Guinea grass variety Co2 recorded a yield of 60 tonnes of green fodder when grown as intercrop. Guinea grass variety CO (GG) 3 recorded an yield of 85 t/ha /year (Fig. 5). Guinea grass has to replanted after 3-4 years.

Fig.4. Hybrid bajra Napier Co3 as intercrop in coconut

Fig. 5. Guinea grass variety CO (GG) 3 as intercrop in coconut

e) Fodder legume

i) Cowpea

Legumes are palatable and protienaceous fodder crops, which have pivotal role in animal production systems. Legume fodders may be mixed with straw or other grasses to prevent the occurrence of bloat and indigestion. Feeding the cattle with balanced quantity of grass with leguminous fodder in the ratio of 3:1 improves the milk productivity. Cow pea is one of the legumes which can adopt well in the CBIFS. The seeds of Co 5 and C 152 were sown with spacing of 30 cm x15 cm. Weeding was done as and when necessary. Fertilizer dose of 16 kg N, 24 kg P_2O_5 and 12 kg K_2O per ha of coconut garden was applied. Harvesting was done 50-60 days after sowing when the crop attains 50 % flowering. From one ha of coconut garden Co 5 and C 152 recorded 15.75 and 13.2 tonnes green fodder yield, respectively. Sowing should be avoided during heavy rainfall. Fodder cowpea can be cultivated as intercrop in the coconut garden or combination of grass + cowpea either 3: 1 ratio or in the intra spaces of coconut as shown in the figure (Fig.6). Cowpea for fodder purpose can be grown in any month under irrigation conditions.

ii) Stylosanthes

Stylosanthes is a leguminous fodder cum cover crop, which is suited for intercropping in coconut gardens, either alone or in combination with other fodder grasses. The plant thrives well in light soils due to its deep rooting system. The crop is suited for growing in warm, humid tropical climate. It is fairly drought resistant and shade tolerant. Sowing is to be done at the onset of southwest monsoon during May-June. Irrigation is required if there is no proper soil moisture at the time of sowing. Different species suitable for cultivation include perennial types viz., Brazilian lucerne *(Stylosanthes guianensis)*, Shrubby Stylo *(Stylosanthes scabra),* short-lived perennial legume Caribbean stylo *(Stylosanthes hamata* cv. Verano) and annual type Townsville stylo *(Stylosanthes humilis).* The seed rate is 2 to 3.5 kg/ha when grown as an intercrop in coconut garden. Seeds broadcasted and covered with a thin layer of soil. The depth of sowing should be 5-10 mm. Seeds germinate within a week. Recommended dose of N, P_2O_5 and K_2O for both annual and perennial stylosanthes are 20, 80 and 30 kg per ha, respectively. For perennial crops, phosphorus @ 80 kg/ha and potash @ 30 kg/ha may be applied in subsequent years. Application of lime @ 375 kg/ha is also recommended in acid soils. Gap filling may be done 15 days after sowing. First weeding is given 45 days after sowing. A second weeding and hoeing may also be done after the first harvest. Gentle raking of the interspace after the application of fertilizers in the subsequent years may be done. First harvest is taken 3-4 months after sowing and subsequent harvest at 45 days intervals or according to the growth of the crop. A maximum of 4-5 harvests can be taken in a year for a perennial crop, which will remain in the field for 3 years (Fig. 7). All these different species of stylosanthes were tried as intercrop in coconut garden. The green fodder yield obtained per year from different stylosanthes species viz., *Stylosanthes guianensis, Stylosanthes hamata and Stylosanthes scabra* when grown in the interspaces of coconut are 23.2 t/ha, 26.3 t/ha and 27.9 t/ha, respectively.

Fig.6. Fodder cowpea as intercrop

Fig. 7. Stylosanthus as intercrop

f) Fodder cereals

i) Fodder maize (Zea mays)

Maize is mainly grown for grain purpose. However, it could be cultivated for fodder purpose also because of its good quality green fodder and high yield. Maize is the most ideal crop for silage making too. In irrigated areas, one crop of maize for fodder purpose may be taken preferably along with cowpea before monsoon, i.e. from March to June to get green fodder during summer. The optimum season for sowing as rainfed crop is the last week of June to second week of July and September to October. For fodder, African Tall and local varieties are recommended. 50-60 kg of seed should be sown per hectare at the spacing of 30 x15 cm. For early crop, seeding should be done during mid March to mid April. Irrigation should be given immediately after sowing and life irrigation should be given on the third day and thereafter once in 10 days. Hoeing and weeding are done as and when necessary. Monsoon crop should be seeded at the beginning of monsoon. 80 kg N and 60 kg P_2O_5 per hectare are recommended to obtain good yield. 50 % N and full P and K should be applied at sowing time and the remaining 50 % N at 30 days after sowing as top dressing. Maize fodder which is up to three weeks old should not be fed to cattle. The crop should be harvested when the cob is in the milky stage. The green fodder yield obtained from fodder maize (variety African tall) under Kasaragod conditions was 26.2 t/ha.

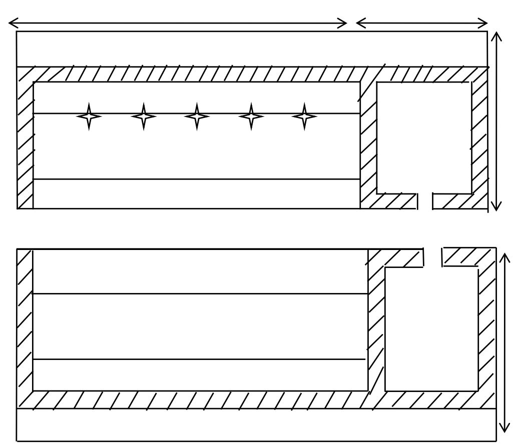
ii) Fodder sorghum

Fodder sorghum is quite soft, palatable and fast growing annual fodder crop adapted to areas up to 1500 m altitude. Under irrigated conditions two crops of sorghum may be taken in one year, one during March to June and the second during monsoon season, i.e. June to October. It should be harvested for fodder purpose after flowering. If harvested at early stage there is risk of hydrocyanine (HCN) poisoning. The recommended spacing is 30 x 10 cm. Irrigation should be given immediately after sowing. Life irrigation should be given on the third day and thereafter once in 10 days. First hand weeding should be done on the 20th day of sowing and if necessary a second hand weeding between 35 – 40 days after sowing. Apply N, P_2O_5 and K_2O fertilizers at the rate of 60, 40 and 20 kg per ha, respectively for Co 27 variety of fodder sorghum. The recommended dose of fertilizer for variety CoFS 29 is 45 : 40 : 40 kg N,P, K/ha as basal and 45 kg N as top dressing after 30 days after sowing followed by the application of 45 kg N/ha after every cut. After 4th cut, apply 40 kg P and 40 kg K along with 45 kg N to sustain the fodder yield and quality. Harvesting should be taken up at 50% flowering for fodder. The fodder varieties tried under coconut as intercrops are viz. CO 27 and CO FS 29 (multicut variety). Co 27 recorded green fodder yield of 22 t/ha and CO FS 29 variety recorded a green fodder yield of 36 t/ha/year.

Dairy

Dairying is an important source of subsidiary income to small and marginal farmers and agricultural labourers. Dairy farming has three dimensional benefits i.e., quick and regular cash return, milk as an excellent food and only source of animal protein to the vegetarian population and supply of manure for the maintenance of soil fertility. The manure from animals provides a good source of organic matter for improving soil fertility and crop yields. The gobar gas if generated from the dung is used as fuel for domestic purposes as also for running engines for drawing water from well. The surplus fodder and agricultural by-products are gainfully utilised for feeding the animals. Since agriculture is mostly seasonal, there is a possibility of finding employment throughout the year for many persons through dairy farming. Thus, dairy also provides employment throughout the year.

In the CBIFS unit at CPCRI, Kasaragod eight cows (seven number of Holstein Friesian and one Jersey cross breed) are maintained so that at least five animals could yield milk throughout the year. A dairy shed should be located at a higher elevated area with good drainage facility (Fig. 10). It should be located to a maximum exposure to the sun in the north and minimum exposure to the sun in the south and protection from prevailing strong wind currents whether hot or cold. Buildings should be placed in such a way that direct sunlight can reach the platforms, gutters and mangers in the cattle shed. As far as possible, the long axis of the dairy shed should be set in the north-south direction. The space required per animal should be 40 sq.ft in shed. In an ideal dairy shed, each animal should be provided 1-1.2 m width and 1.5-1.7 m length as standing space. The floor of the cow shed be non slippery, free from holes and crevices and should have proper slope. Cows are maintained under face out (tail to tail) system. The walls of the sheds should be 1.5 to 2 meters high (Figs. 8 & 9). The roof should be 3-4 metres high. Provide proper shade and cool drinking water in summer. In winter keep animals indoor during night and rain. Maintain sanitary condition around shed. Dispose of dung and urine properly.



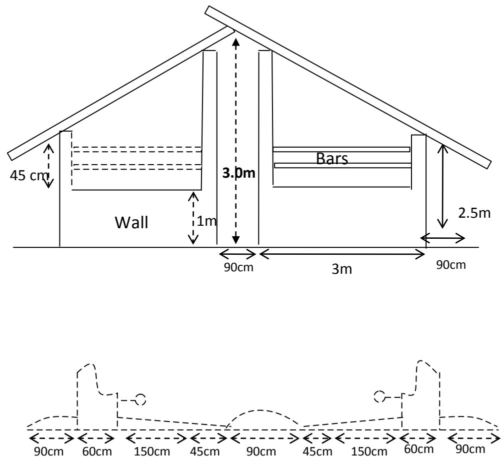


Fig.9 : Elevation and cross section of the cow shed

Pregnant cows should be segregated from others about 15 days to prior to delivery. Necessary care should be taken for the pregnant cow before and after the delivery and also for the new born calf. A resting yard/exercise yard should be made available to the animals for exercise and resting. It should have proper fencing. For proper health animals are allowed to walk in the exercise yard. For this purpose animals were allowed to leave out of the cow shed and entered in to the resting yard after morning milking hours.

Feeding is the major component of cost of milk production accounting for 55-60 per cent of the total cost of milk production. Therefore, judicious feeding is the most important pillar of economical dairying. The dairy animals must be fed on an average 25-30 kg green fodder daily. This was supplemented with the concentrates as per schedule given in the Table 4. The daily ration is usually made up of a concentrate mixture and one or two roughages. It is desirable to use a balanced mixture of several feed ingredients or a compounded feed than using one or two ingredients since the mixture will be more palatable and chances of nutrient deficiencies will be less. This is true in the case of roughages also. The concentrate mixture is made up of protein supplements such as oil cakes (coconut cake, groundnut cake, soyabean meal, gingelly cake), energy sources such as cereal grains (maize, jowar), tapioca chips and laxative feeds such as brans (rice bran, wheat bran, gram husk). Mineral mixture containing major and all the trace elements should be included @ 2 per cent. Ready made concentrates can be purchased from market and used for feeding cattle. However to economize feeding, the concentrate mixture should be home made as the concentrate mixtures available in the market are costlier and their quality in most cases leaves much to be desired. The feed ingredient selected should be unadulterated and free of fungal toxins. Such a mixture should have 14-16 % Digestible crud protein (DCP) and about 70 % total digestible nitrogen (TDN). Some of the recommended concentrate mixtures (approx. 15% DCP, about 70 % TDN) is given in the Table 5. Any one of the mixture can be used depending upon the availability of the material. It may be mentioned that the cost of milk production is always less if major chunk of the daily ration of the dairy animal comprises green fodders.

Table 4. Feed schedule for dairy cattle

Animals	**Concentrate (kg)**	**Green grass (kg)**	**Paddy straw (kg)**
Dry cows (maintenance)	1.25 kg	25-30	1
Milking animals	1 kg for every 2.5 to 3.0 litre of milk + maintenance allowance	30	2
Pregnant animals	1 kg concentrate mixture plus 1/2 kg energy supplement (rice gruel/ ground maize/ tapioca/ tamarind seed meal/jack fruit seed meal) from 6th month of pregnancy in addition to the maintenance and production allowance.	30	2
Calves	1	5	1

Table 5. Ingredient composition of concentrate mixtures (%)

Ingredient	**Concentrate mixture I**	**Concentrate mixture II**	**Concentrate mixture III**
Coconut cake	10	15	25
Gingelly cake	-	20	-
Groundnut cake	30	-	10
Cotton seed cake (decorticated)	-	-	20
Rice bran	30	-	-
Wheat bran	-	30	12
Maize	27	32	30
Mineral mixture	2	2	2
Salt	1	1	1

Drinking water should be readily available to the cow at all times. Regularity in feeding should be followed. Concentrate mixture can be fed at or preferably before milking – half in the morning and the other half in the evening. Half the roughage ration can be fed in the forenoon after watering and cleaning the animals. The other half is fed in the evening, after milking and watering. High yielding animals may be fed three times a day (both roughage and concentrate). Increasing the frequency of concentrate feeding will help maintain normal rumen motility and optimum milk fat levels. Abrupt change in the feed should be avoided. Long and thick stemmed fodders such as Napier may be chopped and fed. Highly moist and tender grasses may be wilted or mixed with straw before feeding. Legume fodders may be mixed with straw or other grasses to prevent the occurrence of bloat and indigestion. Concentrate mixture in the form of mash may be moistened with water and fed immediately. Pellets can be fed as such. All feeds must be stored properly in well ventilated and dry places. Mouldy or otherwise damaged feed should not be fed.

Milk out the udder regularly from the day of calving. Milk can be used for usual human consumption from the 3rd or 4th day onwards. Animals producing more than 12 kg of milk per day can be milked 3 times a day. The intervals between milking should be kept almost equal (>6-8 hours). Care should be taken to maintain hygienic condition. Milking of cows can be done by machines. These work on the principle of negative pressure. A vacuum pump sucks air out of the system. The teat cups are attached to the teats after letting down. Due to sucking action of the machine negative pressure is produced around the teat and milk flows out. From the teat cups the milk is drawn into milk tanks or milk cans through tubes. The main advantage of the milking machine is that labour can be saved. As the milking can be done quicker, the high yielders can be milked completely. Contamination of milk can also be reduced as the milk does not come in contact with outside objects.

Biogas

It was observed that about 50 kg cow dung is necessary to generate 3 m^3 biogas (Fig. 10). With an average daily biogas requirement of 0.56 m^3 per person, the total biogas required to meet the fuel needs of a family consisting of five members will be 2.85 m^3. The slurry obtained from the unit is applied to grass and coconut palms.

Fig.10. Biogas unit

Poultry

a. Broiler

As a component of the CBIFS experiment at CPCRI, a poultry unit of 100 broilers per batch was reared in the deep litter system and a floor space of 1sq. ft. was provided per bird (Fig. 11). Three birds per square meter is an absolute maximum. The shed is provided with good ventilation for free flow of air. Under poor ventilation, the chicks will be weak and predisposed to respiratory diseases. Coir pith, waste material obtained after extraction of coir from husk, is spread as bedding to a height of 5 cm evenly on the floor to conserve the droppings and to prevent loss of nutrients. A very shallow layer of litter on concrete floor was maintained to maximize any cooling effect that the concrete floor may have on the birds through absorption of body heat. Growing houses are thoroughly cleaned and disinfected prior to the transfer of the growing stock. Birds are transferred only during good weather. Clean fresh drinking water is provided at all times. A separate brooding chamber is fabricated to take care of chicks in the initial stages. Brooding is the process of supplying artificial heat to the chicks from the time they are taken out from the incubators up to the time their bodies can control their heat requirements and they are covered with feathers. Day-old broiler chicks are kept in brooding chamber for 14 days and then transferred to the shed. Chicks should have uniform size and color. The weight of a day-old chick should not be less than 33 grams. Broiler birds are given concentrates as per the following feeding schedule (Table 6).

Fig. 11. Broiler birds in the unit

Table 6. Feed requirement of broiler (g/day)

Days	**Upto 3 days**	**4-7 days**	**2nd week**	**3nd week**	**4th week**	**5th week**	**6th week**	**7th week**	**8th week**
Feed	10	20	40	60	80	100	120	120	120

Vitamins, minerals and antibiotic supplements may be added to the drinking water during the first few days. In the CBIFS unit, 4-6 batches of birds in the unit with 100 birds per batch can be maintained. The immediate burning or burying of dead birds is important part of the good sanitation programme. Broilers are marketed when they reach 45-60 days of age depending on gaining the average weight of 1.750 kg.

On an average, 1.5 tones of coir pith enriched with poultry droppings was obtained per annum from the CBIFS unit at CPCRI, Kasaragod with 100 poultry birds per batch and 4-6 batches reared under deep litter system with coir pith as bedding material. The enriched coir pith obtained from the system was recycled. Coir pith, a waste material obtained after extraction of coir from husk, is not easily amenable for decomposition since it is very rich in lignin and cellulose and has a high C:N ratio. Besides, large quantities of coir pith available from the coir industrial units create difficulty for its disposal and also result in environmental problems. One of the ways to overcome these difficulties is to compost the coir pith. It is observed that coir pith can be decomposed faster if it is enriched with poultry droppings. Data presented in Table 7, amply substantiate the observation.

Table 7. Nutrient content of coir pith enriched with broiler droppings vs. raw coir pith

Contents	**Raw Coir pith**	**Coir pith enriched with poultry droppings**
Lignin (%)	30.2	13.2
Cellulose (%)	29.3	16.2
Total Nitrogen (%)	0.34	1.96
Total P (%)	0.02	2.04
Total K (%)	0.48	2.01
Total Mg (%)	0.36	0.54
Total Ca (%)	0.87	0.96
Total Mn (ppm)	128	295
Total Fe (ppm)	1299	1982
Total Zn (ppm)	126	247
Total Cu (ppm)	68	148
pH	6.4	7.2
Organic carbon (%)	28	19.2
C: N Ratio	97:1	11: 1

Aquaculture

Aquaculture as an enterprise that can effectively be integrated with the coconut based mixed farming system. In the semi-intensive aquaculture system as the natural food available in the pond will not be sufficient for the fish, it is necessary to supplement it with cowdung and artificial feed. Hence, cowdung and fodder grass available in the CBIFS can be used as supplementary feed material for the fish. In the CBIFS unit at CPCRI, Kasaragod, a fishpond with the dimension of 27.5 m length, 22.5 m width and 1.5 m depth was constructed (Fig. 12). As the soil is sandy and porous the pond was lined with silpaulin sheets to curtail percolation loss. Preferably, clayey or laterite soil is to be filled upto 10 cm at the bottom of the pond. This soil layer will help to facilitate natural recycling of the food material and to arrest the temperature fluctuations during hot days. The pond water is maintained with the help of internal water source. To facilitate draining of water from the pond whenever needed an outlet pipe is provided at 1 ft. below the embarkment so as to drain the excess water. Both the outlets and the drainpipes are fixed with strainers so that fish does not escape. As the pond is lined with silpaulin sheet, natural ecosystem will not be there and hence artificial aeration is a must. For this, 1 HP blower was installed through which air is pumped in to the pond at 12 different points for proper aeration throughout the pond.

First installment of the supplementary feed is to be supplied into the pond about 24 hours before releasing the fish. Care should be taken to prevent algal growth. About the 4-6 cm fingerlings of four selected species viz. catla (*Catla catla*), Rohu (*Sebeo rohita*), Mrighal (*Cirrhinus mrighla*) and grass carp (*Cteneopharyngodon idellus*) were left in the pond. Generally 1000 fingerlings can be accommodated in 625 m^2. The density of the population depends on the level of management and the number of species of fish.

Use of concentrates helps in quick growth of fish. It is recommended to give mixture of groundnut cake and rice bran in 1: 1 ratio at the rate of 1 to 3 per cent of body weight of fish. These materials are to be mashed thoroughly and made into ball with the help of water and suspended at minimum four places in the pond. Since poultry droppings were available in the system, around 1 kg of poultry droppings were also applied everyday to the pond. This also helps to provide ready-made food for the fish. For grass carp variety, green grass was applied every day.

Normally fish is to be harvested from pond after 10 to 12 months period. Maximum weight of the fish at the end of one year varies from 900 to 1200 g per fish depending upon the variety. The weight ranged from 810 g incase of mrighal to 1180 g in the case of grass carp (Table 9). It is desirable to harvest the fish at periodical intervals so that the remaining ones in the pond can attain good weight.

Table 9. Growth of different varieties of fish (average weight in g/length in cm)

Varieties	**After 1 month**	**After 3 months**	**After 5 months**	**After 8 months**	**After 12 months**
Rohu	13/8.0	86/17	150/23	470/30	850/35
Catla	15/6.5	88/15	250/23	550/30	900/45
Mrighal	12/5.0	82/14.5	145/20	450/25	810/30
Grass carp	25/8.4	90/19.5	275/20	900/36	1180/42

On an average, 400 kg fish is harvested per year from the aquaculture pond in the CBIFS unit at CPCRI, Kasaragod(Fig.13).

Fig.12: Fish pond

Fig. 13: Harvested fish from the fish pond

Azolla

One of the major components of maintenance cost involved in dairy and poultry under the CBIFS is cost of feed. To reduce the maintenance cost it is necessary to find alternate low cost feed material. Azolla is a floating fern, which can be used as an alternative to concentrate feed for livestock and poultry in the coconut based integrated farming system. Azolla is very rich in proteins, essential amino acids, vitamins (vitamin A, vitamin B12 and Beta-carotene), growth promoter intermediaries and minerals like calcium, phosphorous, potassium, iron, copper, magnesium etc. On a dry weight basis, it contains 25 - 35 per cent protein, 10 - 15 per cent minerals and 7 - 10 percent of amino acids, bioactive substances and biopolymers. Azolla can be cultivated by following simple and low cost management practices.

Azolla was introduced in the CBIFS experiment during 2007. A water body was made in the interspace of coconut, with the help of a silpaulin sheet. Silpaulin is a polythene tarpaulin, which is resistant to the ultra violet radiation in sunlight. A pit of 2 x 2 x 0.2 m is dug as a first step. All corners of the pit should be at the same level so that a uniform water level can be maintained. About 10 - 15 kg of sieved fertile soil is uniformly spread over the silpaulin sheet. Slurry made of 2 kg cow dung and 30 g of Super Phosphate mixed in 10 liters of water, is poured onto the sheet. More water is poured on to raise the water level to about 10 cm. About 0.5 - 1 kg of fresh and pure culture of azolla is placed in the water. This will grow rapidly and fill the pit within 10 - 15 days. A mixture of 20 g of Super Phosphate and about 1 kg of cow dung should be added once in every 5 days in order to maintain rapid multiplication of the azolla and to maintain the daily yield of 500 g. A micronutrient mix containing magnesium, iron, copper, sulphur etc., can also be added at weekly intervals to enhance the mineral content of azolla. Three such units of azolla cultivation were maintained in the CBIFS plot.

Azolla should be harvested with a plastic tray having holes of 1 cm^2 mesh size to drain the water. Azolla should be washed to get rid of the cow dung smell. Washing also helps in separating the small plantlets, which drain out of the tray. The plantlets along with water in the bucket can be poured back into the original bed. In case of severe pest attack the best option is to empty the entire bed and lay out a fresh bed in a different location. For poultry, azolla can be fed to layers as well as broilers. It was observed that 10 per cent of the concentrate feed for poultry can be substituted with azolla under the CBIFS.

Fig. 14. Azolla

Impact of Coconut Based Integrated Farming System

a. Effect on coconut yield

In CBIFS, coconut rerecorded higher yield compared to monocropping. The coconut palms maintained under CBIFS receiving integrated nutrient management practices i.e., combined application of organic and chemical fertilizer recorded significantly higher yield which was followed by other treatments under CBIFS. (Table 10).

Table 10. Effect of CBIFS on coconut productivity (nuts/palm)

Treatments	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Monocrop	97	94	81	102	98	108
CBIFS	113	106	108	122	126	137

b. Effect on foliar nutrient levels

The major and secondary nutrient status of coconut palms under the CBIFS was monitored and it was found that there is a positive influence of the organic nutrient source application on the nutrient content of coconut leaves (Table 11). In general, leaf nutrient status were higher under CBIFS compared to monocropping.

Table11. Effect of CBIFS on plant macro, secondary and micronutrients status

Treatments	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
	%					ppm			
Monocrop	1.83	0.12	1.01	0.39	0.187	172.85	7.00	7.30	357.50
CBIFS	1.97	0.14	1.14	0.52	0.211	151.20	8.00	9.45	235.50

N, P, K: Mineralizabe Nitrogen, available phosphorus and available potassium *c. Effect on soil nutrient status*

The soil nutrient status under different treatments in the CBIFS is given in Table 12. In general, soil nutrient status in terms of organic carbon and available N and P were higher under CBIFS compared to monocropping. However, the potassium content was low in the CBIFS treatments compared to monocropping because of the rigorous potassium uptake by both coconut and grass components.

Table 13. Soil nutrient status in the CBIFS (average of two depths 0-25 and 25-50 cm)

Treatments	Organic carbon (per cent)		Nitrogen (kg /ha)		Phosphorous (kg/ha)		Potassium (kg/ha)	
	Coconut basin	Inter space	Coconut basin	Inter space	Coconut basin	Inter space	Coconut basin	Inter space
Monocrop	0.38	0.27	291	197	213	138	162	92
CBIFS	0.44	0.39	301	214	232	198	144	87

d. Effect on soil physical properties

The soil physical properties under different treatments in CBIFS are given in Table 13. CBIFS with organic manure recycling recorded higher water holding capacity, hydraulic conductivity and reduction in bulk density compared to monocropping of coconut. The reduction in the bulk density is due to the application of organic manures, which increased the soil aggregation and pore space, where as the treatments where only the inorganic fertilizers were applied the bulk density was very high due to natural compaction of the red sandy loam soil. This particular limitation of the red sandy loam soil is very well managed when the organic farming practices are followed. Similarly due to the reduced bulk density with high micro pores in the favorable soil structure developed by the application of organic manures, the water holding capacity of the soil is also increased. Hydraulic conductivity was very low in monocropping of coconut than in the treatments to the grass was intercropped.

Table 13. Effect of coconut based integrated farming system on soil physical properties

Treatments	**Water holding capacity (per cent)**	**Bulk Density (g cm^{-3})**	**Hydraulic Conductivity (mm second^{-1})**
Monocrop	17	1.58	0.0037
CBIFS	20	1.42	0.0064

e. Effect on soil microbiology

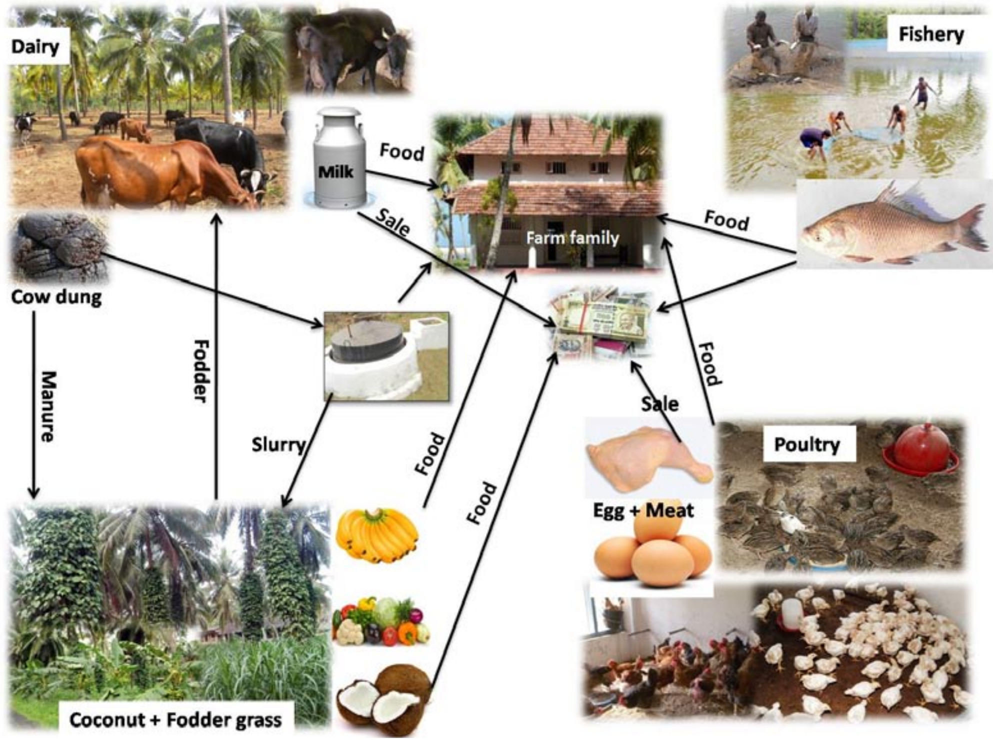
The distribution of soil microbial groups was investigated under CBIFS and monocropping (Table 14). Microbial population indicated that the soil biological activity were more in the farming system when compared to the monocrop of coconut. The organic manures served as a good medium for the microbial growth due to the growth promoting substances and enzymes present in them. Microbial population was comparatively high in the interspaces where the grasses were grown than the coconut basin due to high root biomass available in the grass cropped area. The root turn over in the rhizosphere and root exudates provided a highly conducive environment for the microbial population to multiply.

Table 14. Microbial distribution in coconut based integrated farming system

Treatments	Bacteria 10^5 cfu/g soil		Fungi 10^3 cfu/g soil		Actinomycetes 10^5 cfu/g soil	
	Coconut basin	Inter space	Coconut	Inter space	Coconut	Inter space
Monocrop	13.45	10	6.86	4.16	9.62	6.16
CBIFS	18.22	21.64	16.6	17.23	7.83	12.35

f. Economic analysis of mixed farming system

The sustainability and profitability of the coconut based integrated farming system comprising coconut, pepper (trailed on the coconut trunk), banana (in the border of the plots), fodder grass-Hybrid Bajra Napier cv. Co5 (in the interspaces of coconut), dairy unit (seven cows of Holstein Friesian and one Jersey cross breed), poultry (100 broiler birds), goattery (20 does and two bucks) and aquaculture (1000 fingerlings) was assessed for the year 2016-17. From one ha of coconut based integrated farming system, 22,750 coconuts, 13,275 litres of cow’s milk, 315 kg live weight of goat, 189 kg live weight of broiler birds, 2,535 kg banana, 525 kg pepper and 112 kg fish were obtained. The highest net returns of Rs. 6,10,503/- was realized in the CBIFS. Coconut based integrated farming is an ecologically sustainable system which fetch higher income to cultivators when compared to coconut grown as monocropping. The integration and complementary effects of the system is depicted in the chart below.



g. Employment generation

The annual labour requirement of a pure coconut plantation of one hectare was about 150 man days, of which about 50 per cent labour as diverted for harvesting of coconuts. Under CBIFS Total employment generation in a normal year was about 780-830 man days, and in years when grass slips were to be planted /replanted, their employment potential rose to about 1000 mandays. It indicates that under CBIFS not only the farm family (husband and wife) was getting employment round the year, but also it could provide 50-100 man days work for outside labour.

Conclusion

The experience of maintaining coconut based integrated farming system at CPCRI clearly indicates the scope for the integration of crops and animals in coconut garden for enhancing income and providing employment throughout the year. Resources like sunlight, soil, water and labour were efficiently utilized. Subsidiary income was realized from all the component units. Besides enhancing coconut yield, there was substantial improvement in soil and plant health status, soil physical properties and soil biology. All the above fact makes the CBIFS more economically feasible and ecologically sustainable than monocropping.

Nutrient management in coconut based farming system – Concept and practices

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INTRODUCTION

Coconut gardens offer excellent opportunities to exploit the inter-space potential for maximizing returns per unit area. Coconut based cropping/farming systems involving cultivation of compatible crops in the interspaces of coconut and integration with other enterprises like dairying offer considerable scope for increasing production and productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour. In humid tropics, higher efficiency of utilisation of the basic resources of crop production viz. land, solar radiation and water can be achieved by adopting intensive cropping systems (Nelliat, 1973). Coconut, being a perennial crop, lives for decades together and needs congenial growth conditions to maintain the growth and give sustained yield. Once the palm starts bearing, on an average, produces one leaf and one inflorescence every month. It takes 44 months for an inflorescence bud to grow and develop into nuts. The palm crown has inflorescences at different stages of development throughout the year. Since growth and production in palms is simultaneous, no critical growth period is defined as in the case of field crops. Thus coconut needs continuous supply of moisture and nutrients throughout its life time. Coconut exports nutrients to the above ground parts continuously from limited volume of soil throughout its growth. The annual nutrient export to various parts of the palm viz. nuts, fronds, trunk, bunch and spathe vary from 20 to 174 kg N, 2.5 to 20 kg P and 35 to 249 kg K ha-1. Since the soil is not an inexhaustible source of nutrients, there is a need to replenish the soil regularly with nutrients to avoid nutrient depletion over a period of time. Any deficiency of nutrients at any stage will adversely affect the growth and yield of coconut. Unlike inorganic fertilizers, the nutrient supply from organic manure is slow and steady apart from very low nutrient loss and the availability of micronutrients coupled with the added advantage of improving soil physico-chemical and biological properties. Thus application organics to coconut is more needed for continued supply of nutrients and improving soil health.

With the advent of green revolution, the chemical inputs have become the mainstay of Indian agriculture. Nevertheless, this led to a decline in the use of organic manure. Dependence on chemical fertilizers has brought with it many problems facing modern agriculture. Though not so profound, yet soil degradation is one of its outcomes. The answer for overcoming these problems is the use of more and more organic manures. This concept attains greater importance in coconut as the fertility status of the coconut growing soils in India is mostly below average. One of the reasons for the reduced organic matter application, which can maintain the soil health, is lack of availability of organic matter due to increase in area under crop cultivation. Thus it was felt that recycling of the wastes available from the existing garden and use of biofertlizers would be a better proposition for improving organic matter content in soil.

Poor soil resource base

The coconut growing soils can be grouped mainly under four different soil orders viz. Alfisols, Entisols, Ultisols and Inceptisols. Most of these soils are low in native fertility, but are fertile enough to support fairly successful crop growth. It has been well accepted and documented that most of the soil conditions suitable for main crop coconut, also satisfies the requirement of many intercrops grown in association (Magat, 1990) (Table 1). In fact, soils with moderate base saturation such as Alfisols and Inceptisols could be more suitable for coconut based cropping system. In India, most of the coconut growing soils such as sandy loam, laterite and lateritic, red (loamy) and alluvial soils support a suitable intensive multiple cropping (Nair, 1979). It should also be realized that nutrient management in these soils assume significance as coconut and component crops in the system requires continuous supply of nutrients throughout their life period for higher productivity.

Table 1: Soil requirements of coconut and its intercrop for high yields

Crop	Soil depth (cm)	Drainage	Soil pH	Soil type	Major macro nutrients**
Coconut	>75	Moderate to well drained	6.0-7.5	Sandy	N, K, Cl, S, P
				Loamy	
				Clayey*	
Intercrops					
Corn	>50	Well drained	5.3-7.3	Loamy	N, P, K, S
Groundnut	>50	Well drained	5.8-6.2	Loamy	N, P, K, Ca, S
Pineapple	>75	Well drained	4.5-5.5	Sandy	N, P, K, Ca
				Loamy	
				Clayey	
Banana	>75	Well drained	6.0-7.5	Loamy	N, P, K, Ca
				Clayey	
Coffee	>75	Well drained	4.5-6.5	Loamy	N, P, K, Ca, S
				Clayey	
Cocoa	>75	Well drained	5.5-7.0	Loamy	N, P, K, Ca, S
				Clayey	

* Sandy and clayey soils suited if soil is well drained, friable and with good structure (not compacted and aerated)

** Micronutrients Zn, Fe, Mn, B, Cu must be adequate

Source: Magat (1990)

Nutrient management

Presently, agriculture research places more emphasis on sustainability of production system. Sustainability, in fact is a dynamic term implying satisfying the ever changing human needs without in any way sacrificing the quality of life. In achieving sustainability in agriculture we may have to understand here that no single resource is more important than soil, which is storehouse of essential nutrients for plants, provide water and anchorage to the crops, which it supports. It is here that the integrated nutrient management, which lays emphasis on improving and maintaining soil fertility for sustained productivity, forms one of its crucial pillars (Khan *et. al.* 2000).

Integrated nutrient management includes the intelligent use of organic, inorganic and online biological resources (BNF) so as to sustain optimum yields, improve or maintain soil's chemical and physical properties and provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe (Tandon, 1990). Infact, this covers in short the economics of cultivation as well as environment.

Nutrient management in cropping/ farming system is difficult as it involves interplay of various factors like crop requirements, differential crop responses, crop residue additions, management practices suiting crop needs, water requirement and soil environment. It is therefore imperative that whole system must be considered as one unit. Experience in coconut based cropping system suggests that it is necessary to fertilize coconut and component crops according to the nutrient requirement of individual crops to make the system more productive and competitive (Liyanage, 1985; Margate *et. al.* 1994).

On farm waste recycling in cropping system

In the premier coconut growing state of Kerala in India, many crop combinations with coconut have evolved over years to mainly satisfy home needs. This approach has changed over years and commercial inter / mixed cropping ventures are in vogue in the southern states of Andhra Pradesh, Karnataka and Tamil Nadu. EYM, banana and cocoa are major crops. There is a renewed interest among farmers to grow vanilla, patcholi besides medicinal plants. Such coconut-based cropping/ farming systems also generates huge amount of biomass. Studies in India and else where have shown that a major part of these can be recycled in an effective manner for ecological sustenance. It has been estimated that the biomass production by coconut-pineapple cropping system was 4.3 times that of pure coconut stands, so this combination is considered to be one of the optimum cultivation patterns in tropical areas (Peng-Fang Ren *et. al.* 1996). Studies at Kasaragod have revealed that cocoa as a mixed crop in coconut garden added to the soil 818 and 1985 kg (oven dry wt.) per hectare per year of biomass through shed leaves and pruning under single and double hedge systems respectively. As much as 50 kg N, 4.85 kg P and 29.1 kg K per hectare could be returned to the soil every year under the double hedge cocoa system (Varghese *et. al.* 1978). The addition of large amount of organic refuses by the cocoa was found to improve the soil physico-chemical characteristics and there by positively influence the yield of coconut (Table 2).

Table 2: Influence of mixed cropping of coconut with cocoa on productivity of palms

Cropping system	**Coconut yield (nuts/palm/year)**	
	Pre-experimental period **(1966-70)**	Experimental period **(1972-87)**
Coconut sole crop	68	107 (157)*
Coconut + cacao (single hedge)	57	108 (189)
Coconut + cacao (double hedge)	39	89 (228)

* Fig. in parenthesis indicate % increase in yield

The total removable biomass (in terms of fronds, bunch waste, nuts in case of coconut, fallen leaves and flower buds in clove, above ground biomass for banana and fruits, crown and leaves in case of pineapple) from the system was 19.1 t/ha in the control plot and ranged between 20.11 and 27.55 t/ha under graded levels of fertilizer (Fig.1). In this the contribution from coconut alone was approximately 85 % (Fig.1A). However, availability of biomass for recycling in the system was around 12.7 t to 18.2 t per hectare under various treatments. This biomass if recycled can enhance the productivity and sustenance of the system in terms of nutrient need besides economic benefits (Fig. 2). Studies are in progress at CPCRI, Kasaragod.

In a study aimed at integrating on farm wastes in a coconut based mixed cropping system, in the alluvial soil region of Andhra Pradesh the biomass generated was 6.7 t/ha in mono cropping system compared to 14.87 and 29.02 t/ha depending upon the coconut based component crops in the system (Table 3).

Fig. 1: Total removable biomass from the system

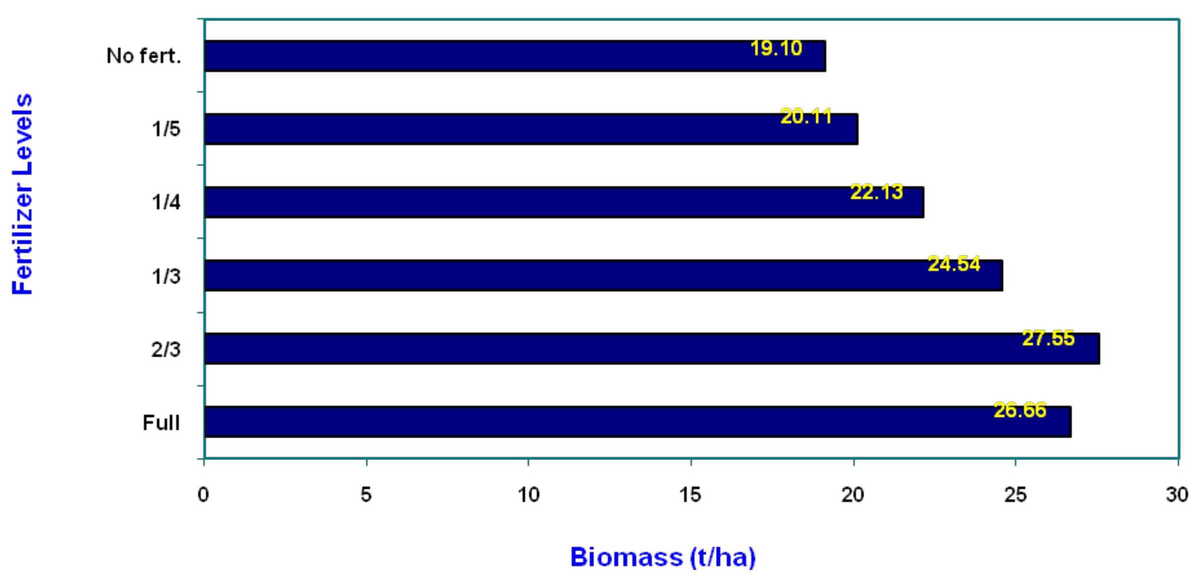


Fig. 1A: Per cent contribution of crops to removable biomass

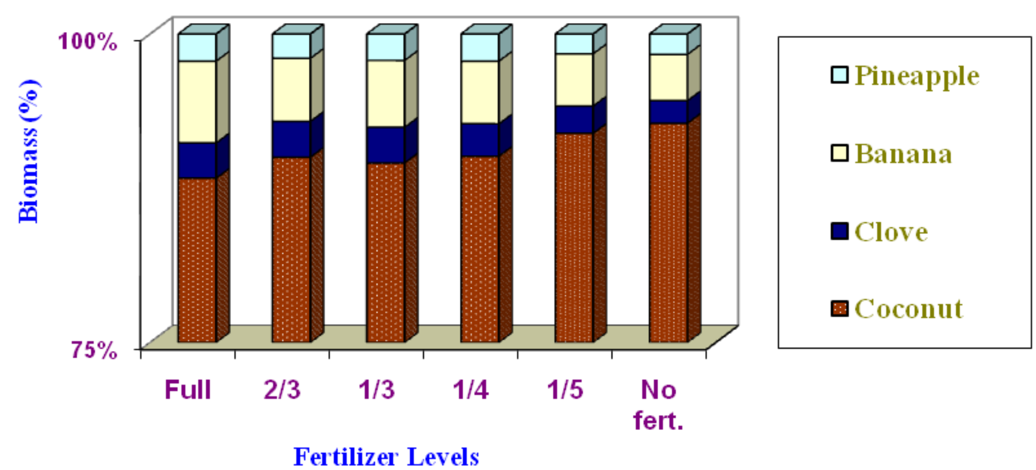


Fig. 2: Extent of nutrient recycling under different levels of fertilizer input - Coconut

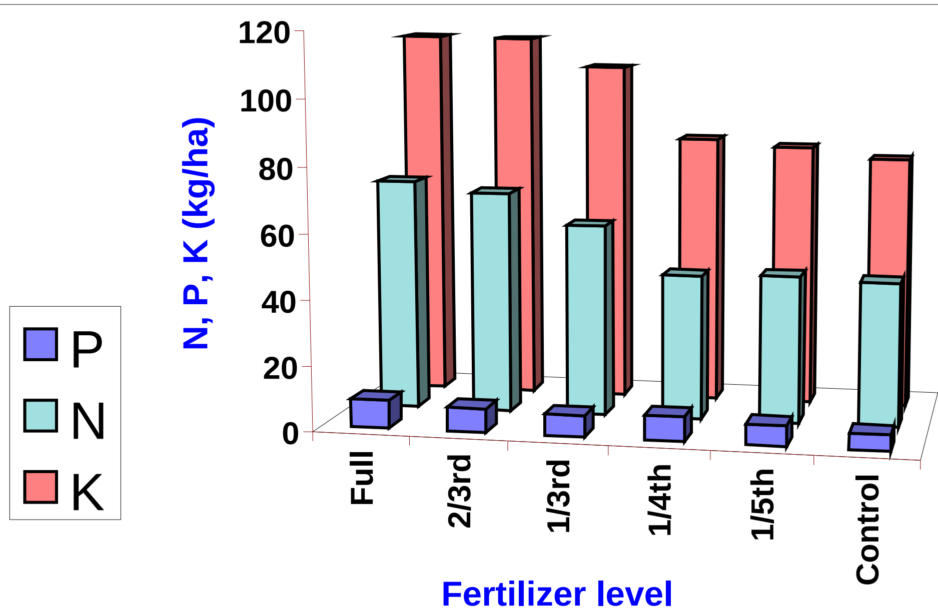


Table 3: Amount of biomass generated in a coconut based mixed cropping system in Ambajipeta, West Godavari Dt., Andhra Pradesh, India

Cropping system models	**Biomass generated (t/ha)**	**Percent recovery as vermicompost**	**Nutrient recovery (kg/ha)**		
			N	**P**	**K**
Model I	29.02	55.6	209.8	22.54	57.6
Model II	14.87	58.0	112.3	12.03	30.8
Model III	6.77	60.8	53.5	5.76	14.7

Model I: Coconut (ECT), cocoa, pepper, pineapple, banana, turmeric, EFYam, colocassia
Model II: Coconut (ECT), pepper, pineapple, banana, turmeric, EF Yam, colocassia
Model III: Coconut (ECT) mono crop
Source: Srinivasulu *et. al.* (2002)

Coconut Based Farming system

Integration of crops and livestock in the coconut garden is also widely practiced in majority of the coconut growing areas generate not only additional income, and also provide relief against the fluctuating prices of nuts besides generating more employment. The recycling of waste produced in the system improves the soil health and thus provides ecological sustenance to the system. An intelligent farmer can make his system self-sustaining by resorting to these activities.

At Kasaragod (India) in a mixed farming unit (1.2 hectare) comprising coconut, pepper, fodder grass, mulberry, dairy, poultry and pisciculture has brought out the importance of the system for better nutrient management. The system generates huge quantity of waste biomass, which will meet 74 % N, entire quantity of P, and 82 % of K requirement of both coconut and grass (Table 4). The yield of the palms in the system increased from 59 nuts /palm/year to 97 nuts /palm/year.

Table 4: Nutrient flow in the coconut based farming system

Items	Quantity	N (kg)	P (kg)	K (kg)
A) Nutrient contribution by the components of the system				
Cow dung	14 tonnes	98.00	70.00	105.00
Poultry	295 kg	1.92	2.36	2.08
Silk worm	12 kg	0.11	0.05	0.09
Cows urine and cowshed washings	50,000 litres	30.00	-	28.00
Total		130.03	72.41	135.17
B**) Nutrient substitution through recycling of the coconut fronds (minus petiole)**				
Coconut Leaves (in terms of vermicompost)	1.45 tonnes	26.14	4.36	6.94
Total (A+B)		156.17	76.77	142.11
C) Inorganic addition to the system				
i) Coconut palms	500 g N, 320 g P_2O_5, 1200 g K_2O (per palm basis)	79.00	22.12	157.37
ii) Grass*	160: 20: 20	131.2	16.4	16.4
Total (i + ii)		210.2	38.52	173.77
Percent supplementation of inorganics through on-farm waste recycling				
Percent supplementation		74.29	Entire	81.78

*Full P (80 kg) & K (80 kg) dose is applied at the time of planting.
Fresh grass is planted every four years. So shown as split for each year.
Soil type – *Arenic Paleustults*

From the available data in the coconut based farming system, it is apparent that system is highly dynamic with complex interactions. The high biomass production and its recycling triggers favourable biological activities which over long period of time can stabilize the self generating power of the system (Bavappa, 2000).

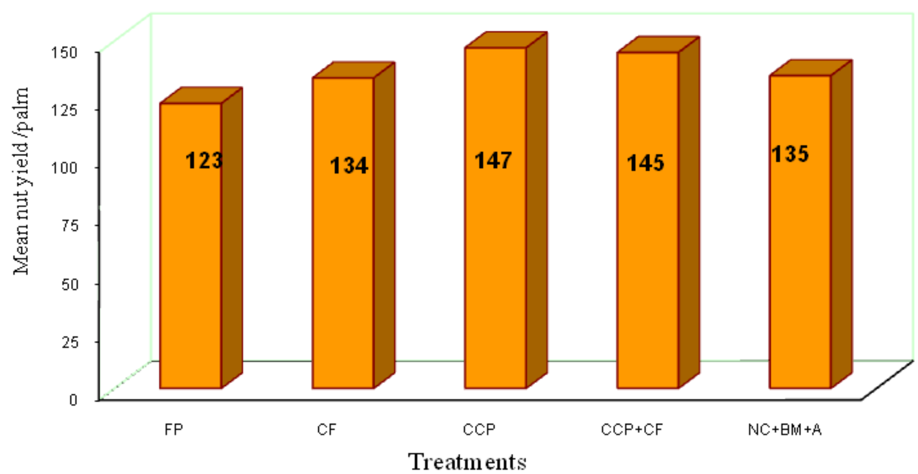
Integrated nutrient management in coconut

In Kerala it is common practice to manure palms with green leaves after sessation of monsoon. Of late, this has turned out to be a costly venture due to transport cost. Thomas and Shantaram (1984) have advocated basin management in coconut, which involves cultivation of leguminous creepers such as *Pueraria phaseoloides*, *Mimosa invisa* and *Calapogonium mucunoides* during the monsoon period from June to October and incorporation of legume biomass (18-24 kg) in respective basins. Experimental evidences indicate the feasibility of substituting up to 50 % of fertilizer N with the nitrogen contributed by leguminous covers.

However, coconut *perse* produces large quantities of biomass viz. husk, dried leaves, coir dust etc. that can be effectively recycled back into the system to reduce the nutrient requirement of the crop through chemical fertilizers. It has been estimated that from coconut (excluding coir pith) approximately 11.2 million tones of waste is likely to be available for recycling (Biddappa *et. al*. 1996). The recycling of the coconut waste will add 79.15, 7.6 and 49.45 thousand tones of N, P_2O_5 and K_2O respectively (Nair *et al.* 1996).

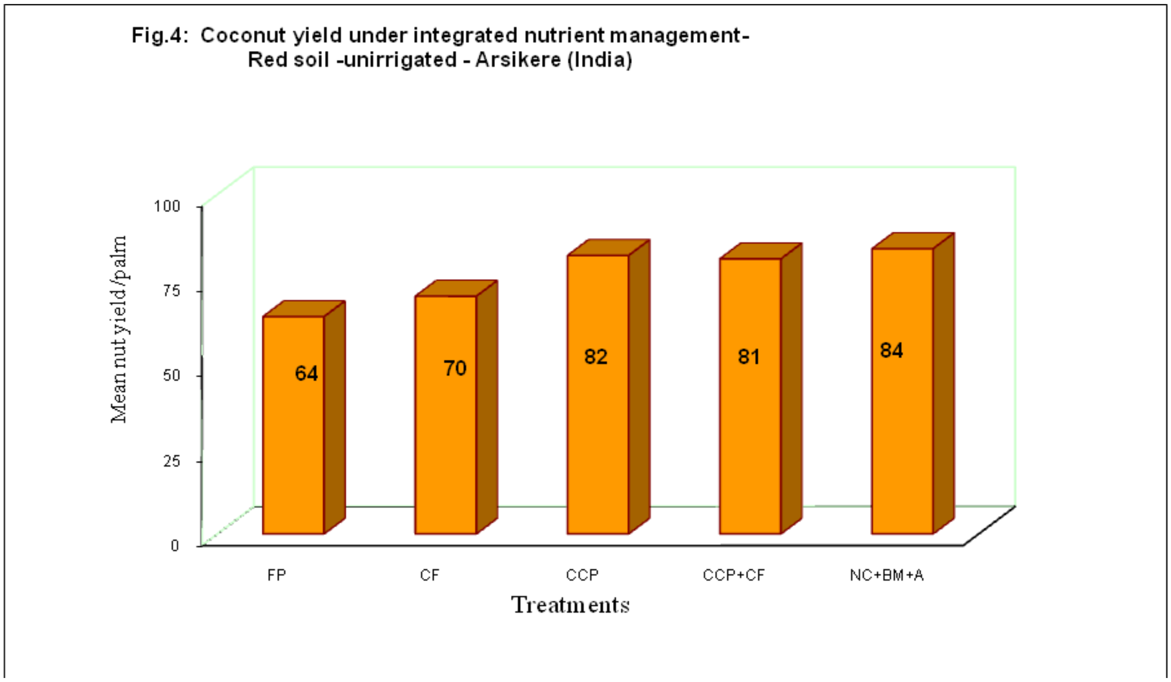
Countrywide experiments were started under the All India Coordinated Research Project on palms (Anon. 2000b) on INM of coconut plantations. In the red soil region under irrigated conditions of Aliyarnagar, Tamil Nadu integrated management practices gave yields more or less equal to that of chemical fertilizers (Fig.3).

Fig.3: Coconut yield under integrated nutrient management
Red soil - irrigated - Aliyarnagar (India)

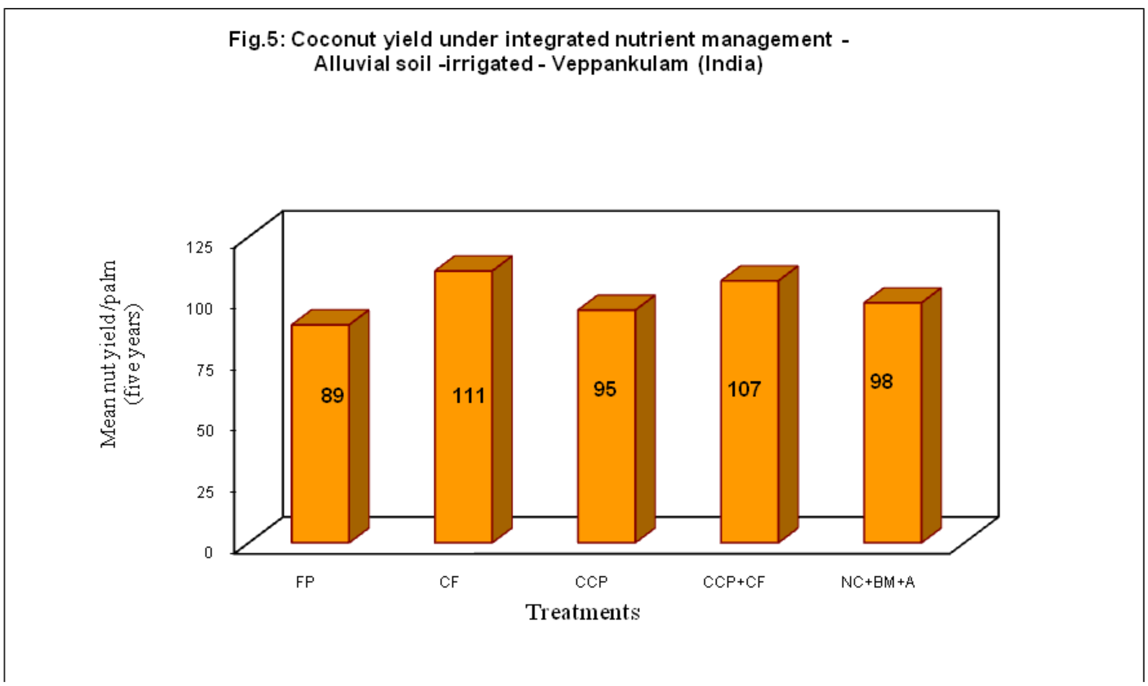


FP	Farmer's practice	CCP + CF	Composted Coir pith + Chemical Fertilizer
CF	Chemical Fertilizer	NC + BM + A	Neem cake + Bone meal + Ash
CCP	Composted Coir pith		

In the semi arid tract of Arsikere, Karnataka (India), the yield varied between 81 and 84 nuts/palm/year under INM treatments compared to 70 nuts/palm/year under chemical fertilizers.



In the alluvial soil region of Veppankulam, Tamil Nadu, the yield of palms under the INM treatments varied between 95 and 107 nuts/palm/year (Fig.5). Interestingly, the yields under the treatment composted coir pith with chemical fertilizers were at par with yields obtained under full chemical fertilizers.



With little efforts gliricidia can be a successful green leaf manure crop, which can be grown as a mixed crop with coconut in coastal sandy soils. Recent studies at CPCRI indicated that gliricidia could yield 2.3 t /ha of lopping, which can meet 88 % nitrogen, 23 % phosphorous and 15.3 % potassium requirement of the palms (Table 5).

Table 5: Nutrient substitution through gliricidia loppings in coconut

	Nutrients		
	N	**P**	**K**
Coconut			
Fertilizer recommendation (g/palm/year)	500	140	1000
Total fertilizer nutrient needs (175 trees; kg/ha)	87.5	24.5	175
Gliricidia			
Nutrient content of loppings (%)	3.38	0.247	1.165
Nutrient availability through gliricidia biomass (2.3 t/ha) addition (kg/ha)*	77.74	5.68	26.80
Fertilizer nutrient substitution by gliricidia			
% substitution	88.0	23.0	15.3

* Gliricidia 3 rows between palms spaced 7.5 x 7.5 m, 3 prunings in a year

Source: Subramanian *et. al.* 2000

NUTRIENT DEFICIENCY SYMPTOMS, DIAGNOSIS AND REMEDIATION IN COCONUT

ROLE OF NITROGEN (N)

- It promotes growth
- Facilitates better leaf production and chlorophyll production
- It encourages vegetative growth of plant and imparts deep green colour to the leaves
- Nitrogen is a constituent of amino acids, proteins and nucleic acids.

Nitrogen deficiency symptoms are commonly seen in light textured sandy soils poor in organic matter and also in water logged conditions. Nitrogen being mobile in the plant system deficiency symptoms first appears in the older leaves

Deficiency symptoms

- Loss of normal healthy green colour in the initial stage and becomes yellowish green and the whole foliage exhibits slight and continuous yellowing
- As the deficiency progresses, the older leaves develop a uniform golden yellow colour, whereas, the younger leaves turn pale green giving the leaflets a dull appearance
- Reduction in chlorophyll content with golden yellow colouration of older leaves near the petioles and light brown colour near the end, which later dries out
- Yellowing starts from the tip of the leaf and leaflets and progresses along the midrib
- Mid rib turns yellow
- The size of the leaves gradually gets reduced and the number of functioning leaves becomes less
- In advanced stage, the stem below the crown narrows down to a 'pencil point' with a few short leaves on the crown
- Abortion of inflorescences and fail to emerge. If emerges, it will be with little or very little female flowers. Growth virtually stops when N deficiency is very severe and the palm turns barren.

N deficiency can be confused with Fe or S deficiency, although the chlorosis in those deficiencies is typically most severe on the youngest leaves, whereas, the older leaves are affected in the case for N deficiency.

Remediation

The deficiency can be managed through the application of nitrogenous fertilizers depending on the soil test data.

ROLE OF PHOSPHORUS (P)

Phosphorus (P) is an important constituent of nucleic acid and is abundant in the young tissues. Initial flowering of young palms is greatly influenced by the supply of P. Phosphorus, essential macronutrient, is involved in photosynthesis, respiration, energy storage and transfer, cell division, and enlargement. Phosphorus promotes early root formation and growth. The content of P in the leaves will be lower in summer indicating the minimum flux during such period.

P deficiency in coconut

P deficiency occurs in crops grown in the lateritic and poor sandy soils. But due to continuous application of chemical fertilizers, there will be build up of P in the soil which increases the availability in soils.

The deficiency symptoms are usually seen in palms grown in extremely acidic as well as in calcareous soils.

Deficiency symptoms

- Leaves become purple coloured, and in severe cases, leaves may turn yellow.
- Premature drying and shedding of leaves are also seen.
- The symptoms of slowing down of growth and shortening of fronds are found to be associated with P deficiency.

Remediation

Application of P fertilizers based on soil test value. Correction of P deficiency improves overall nutrition of the palm and produces beneficial effects on the number of nuts and yield of copra per nut.

ROLE OF POTASSIUM (K)

Potassium is required in relatively large amounts in palms and it facilitates several major functions. This nutrient is involved in photosynthesis, enzyme activation and osmoregulation. It plays vital role in the formation of amino acids and proteins and in the photosynthetic activities of the plant. It is essential for starch formation and the translocation of sugars and also in the development of chlorophyll. It increases leaf area, improves leaf angle and leaf colour which result in better utilisation of sunlight and ultimately causes increased number of fronds, inflorescences, female flowers, nut set and weight of copra per nut. It imparts resistance to pest and disease attack along with regulating water balance of the plant. It also enables the plant to withstand drought. Osmoregulation affects the pressure within a plant cell: potassium controls the opening and closing of stomata. If potassium levels in soils are low, plant leaves develop symptoms of water stress. Palms may also become more susceptible to disease if important elements, including potassium, nitrogen, boron, and magnesium, are out of balance in soils.

K deficiency in coconut

The deficiency is common in light sandy soils as well as in laterite soils. High levels of calcium and magnesium in soil results in depletion of this nutrient from the root zone. Intercropping with potassium exhaustive crops such as tapioca, fodder grass, banana and pineapple without proper addition of fertilizers would also result in the depletion of potassium.

Deficiency symptoms

- Development of orangish yellow discoloration from the tip of the leaflets, progressing along the margin towards the base.
- If severe, tip of leaflets withers and become necrotic
- The midrib remains green and some leaves exhibit a scorched appearance
- Appearance of a green triangle with it's base in the lowest leaflets and apex towards the tip is a characteristic feature of potassium deficiency in coconut.
- Newly emerging leaves are short and chlorotic or yellow.
- Reduced growth, slender stem, short leaflets and reduction in inflorescences, nut set and nuts per bunch

Remediation

Application of K fertilizers based on soil test prevents K deficiency

ROLE OF CALCIUM

Calcium (Ca) is an immobile element in plant. It is a constituent of cell walls and is essential for the growth of meristems, cell division, particularly for the growth and functioning of root tips, and bud formation. In coconut, apart from the role of a nutrient, it acts as a soil ameliorant, especially under acidic conditions. This is also involved in nitrogen metabolism, reduces plant respiration, aids in translocation of photosynthesis from leaves to fruiting organs and stimulates microbial activity

Deficiency symptoms

Clear cases of Ca deficiency in coconut are not usually found. However, the deficiency symptoms first appear on the youngest leaves.

- Young leaves exhibit narrow white bands at margins. Later it gains a rusty appearance in leaf margin.
- Along with this there will be rolling up of leaves.
- Yellowing of leaflet tips with yellow to orange ring shaped spots spread on the leaflets, later turn necrotic and further drying up of leaf. These symptoms appear in the middle leaves earlier than in the older leaves. Severe distortion of leaflets and leaves also occur.

Remediation

Regulated applications of Ca bearing fertilizers like rock phosphate, super phosphate, bone meal or soil application of lime or dolomite @ 1 kg per palm per year depending on the lime requirement of the soil is recommended.

ROLE OF MAGNESIUM (Mg)

Magnesium (Mg) is the only metal constituent of chlorophyll, the green colouring matter of plants and hence has a definite role in the pigment system and affects the photosynthetic capacity of the plant. It plays an important role as a 'carrier' in the transport of P in plants. It also plays an important role in the production of carbohydrates, proteins and fats. Magnesium is the key element of chlorophyll production. It improves utilization and mobility of phosphorus and also acts as an activator and component of many plant enzymes. It facilitates increased iron utilization in plants.

Deficiency symptoms

- Mg deficiency appears on the older leaves of palms
- Presence of broad chlorotic (yellow) bands along the margins
- Leaves in the lower half of the crown are bright yellow, while leaves on the upper half remain green
- Yellowing of the older leaves, which starts from the tip and extends towards the base and later the younger leaves also turns yellow
- Mg deficient leaves have distinctly green leaf centres and bright lemon yellow to orange coloured margins
- Yellowing occurs principally in those parts of the leaf which are exposed to sunlight, whereas, the shaded part remains green
- Bronzed appearance of older leaves which dry out later
- Necrosis of leaflets which turn reddish brown with translucent spots

Mg deficiency symptoms differ from those of K deficiency wherein, the symptom severity of discoloration in K deficient leaves is usually orange to bronze, shading gradually to green at the base of the leaf, whereas Mg deficient leaves have distinctly green leaf centres and bright lemon yellow to orange margins. Mg deficiency reduces coconut yield by about 40 %. Dwarf palms are more sensitive to Mg deficiency than tall and hybrids.

Mg deficiency symptom on coconut

Remediation

Application of dolomite @ 1 kg per palm, two weeks prior to fertilizer application, or magnesium sulphate @ 500 g per palm along with second dose of fertilizer application would help in managing the deficiency.

ROLE OF SULPHUR

Sulphur (S) is a constituent of protein and it aids in the formation of chlorophyll. It helps in the development of dark green leaves and an extensive root system.

Diagnosis

- Leaflets become yellowish - green or yellowish – orange
- Chlorosis and necrosis increase with the age of the leaves
- In severe cases, second or even the first leaf may show yellowing
- Drooping of the leaves as the stem becomes weak
- In older palms, leaf number and size are reduced
- The number of live fronds becomes fewer.
- In the advanced stage, the crown loses most of the leaves and severe necrosis is found on the older leaves.
- The yield of nuts is reduced and the nuts are usually small with normal kernel thickness.
- On drying, the kernel collapses into soft flexible and leathery copra, often brown in colour which is usually referred to as "***rubbery copra*".**
- It has very poor physical and chemical characteristics, particularly with very low oil content.

Remediation

S deficiency in coconut can be prevented by the regular use of S containing fertilizers like Ammonium Sulphate, Super Phosphate, Magnesium Sulphate *etc*.

ROLE OF IRON (Fe)

Iron (Fe) is a catalyst for the formation of chlorophyll and is also a constituent of enzymes associated with respiration and oxidation systems. Usually appears on palms grown in poorly aerated soils or those that have been planted too deeply. Water logged soils and deep planting suffocate the roots and reduce their effectiveness in taking up nutrients such as Fe. Under acidic soil conditions, deficiency of Fe is usually not encountered.

Deficiency symptoms

- Uniform chlorosis *ie.,* a pale green or dark yellow discolouration occurs to all the leaves from the top of the crown to the base
- Gradual yellowing of the leaflets in longitudinal strips parallel to the veins
- In the advanced stages the leaf becomes completely yellow
- Shortening of the rachis and the leaflets
- Absence of necrosis in any part of the leaf is a characteristic symptom of iron deficiency.

Fe deficiency symptoms on coconut

Remediation

Application of $FeSO_4$ @ 0.25 to 0.5 kg / palm / year is recommended as the management practice for correcting the deficiency.

ROLE OF MANGANESE (Mn)

Visual symptoms may be sufficient to diagnose this disorder, but leaf nutrient analysis is also suggested, since symptoms of boron (B) deficiency can be similar. Mn deficiency is caused primarily by high soil pH and as in the case of Fe, deficiency of Mn occurs in alkaline and calcareous soils, where it gets immobilized in the coconut root zone.

Deficiency symptoms

- Newer leaves with chlorotic and longitudinal necrotic streaks
- As the deficiency progresses, newly emerging leaflets appear necrotic and withered on all except the basal portions of the leaflets
- This withering results in curling of the leaflets about the rachis giving the leaf a frizzled appearance (‘***frizzle top***’).
- In severely Mn - deficient palms, growth stops and newly emerging leaves consist solely of necrotic petiole stubs.

Mn deficiency in coconut

Remediation

Soil application of $MnSO_4$ @ 25kg/ha is recommended as the management practice for correcting the deficiency.

ROLE OF COPPER

Deficiency of copper (Cu) is seen in highly acid sandy soils and in heavy organic soils, highly calcareous and alkaline sols. Liming reduces the availability of copper in deficient soils.

Deficiency symptoms

- The deficiency symptoms are severe bending of the rachis of the youngest leaves accompanied by yellowing and desiccation of the leaf tip which is rimmed with brown and yellow and the central part remains green.
- As the symptoms develop, dried out part spreads and gives the palm a saggy appearance
- Most of the petioles will be in arc - shape, eventually losing turgidity
- The leaflets show premature dry up and necrosis of the tips and change in colour from dark green to yellow from the tips towards the leaf petiole

ROLE OF ZINC (Zn)

Zinc (Zn) catalyses oxidation in plant cells, is essential for the transformation of carbohydrates, helps in the formation of auxins, and promotes water absorption. Zn deficiency usually occurs in saline soils.

Deficiency symptoms

- Button shedding along with the shortening of the crown is the reported symptom of zinc
- Zinc deficiency is characterized by formation of small leaves wherein the leaf size gets reduced to 50 %
- Leaflets become chlorotic, narrow and reduced in length
- In acute deficiency, flowering is delayed

Remediation

Soil application of $ZnSO_4$ @ 25 kg / ha is recommended as the management practice for correcting the deficiency

ROLE OF CHLORINE (Cl)

Chlorine (Cl) has a role in the stomatal conductance and in the maintenance of water balance. The deficiency of Cl is seen the palms located in the inland areas. Chlorine is normally considered as a micronutrient element for higher plants. It's importance in the nutrition of coconut has been emphasized recently. Since Cl requirement of coconut is comparatively very high, it is considered as a major nutrient for the crop. It enhances the growth of young palms and increases the yield of bearing palms. The effect of Cl is manifested more on the thickness of the kernel and the copra out turn.

Deficiency symptoms

- Presence of abnormal leaves
- Reduced growth rate of the palms with reduction in size and number of nuts

- Drooping of leaves that indicates signs of moisture stress which may result in the breakage of fronds
- Stem cracking and frequent occurrence of stem bleeding
- Marked incidence of grey leaf blight is also reported
- The leaflets become susceptible to fungal attack and cause ***“leaf spots”.***

Remediation

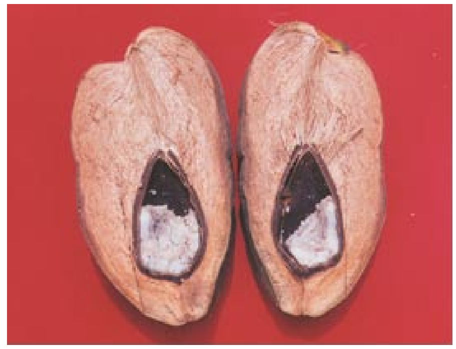
Sodium Chloride (NaCl: common salt) can be used for supplementing the Cl requirement of the palm, particularly in the case of plantations situated away from sea coast.

ROLE OF BORON

Boron is an essential micronutrient for coconut, which helps in the multiplication of meristematic tissues. It helps in the metabolism of protein, synthesis of pectin, maintenance of water relation, translocation of sugars, tissue respiration, fruiting process, growth of pollen tube and in the development of flowers and fruits. Wide spread deficiency of boron is noticed in the coconut growing areas, which may be attributed to the continuous removal through cropping and due to the non-replenishment of the same along with regular fertilizer application. The deficiency symptoms of boron are very much specific. Boron deficiency has been reported from different coconut growing countries of the world and the problem is commonly known as ***'crown rot / choking'*** disease of coconut. Since boron is an immobile element in plant, initial symptoms appear on the youngest leaf.

Deficiency symptoms

- Initial symptoms of boron deficiency are manifested by reduction in the elongation of young leaves.
- The leaflets, when unfolding, are crinkled and will be shorter than normal.
- In more advanced stages, terminal leaflets remain fused.
- The tips of these leaflets may be ‘knife shaped’, with or without a brown solution oozing out through the hook. This symptom is also called ***‘hook leaf’***.
- The basal part of the petiole may be without leaflets.
- In adult palms, the deficiency leads to production of ***branched spikes***, premature death of inflorescence, and production of inflorescence with lesser female flowers, and shedding of buttons (female flowers).
- Other associated symptoms include ‘***Hen and Chick’*** symptom (a few under developed nuts / small sized nuts along with full developed nuts),
- Cracking of nuts externally /internally with meat protruding towards the mesocarp and barren nuts with partial/unevenly developed kernel having poor quality copra. Pollen production, pollen grain germination and pollen tube development will be affected.
- Often, the malformations may be exhibited either singly or by various combinations based on the intensity of the deficiency. Drought may aggravate boron deficiency and in some cases seasonal boron deficiency *i.e*., the symptoms appearing in the dry season and disappearing in the wet season could be noticed.



Boron deficiency symptoms in coconut

Integrated Pest Management in coconut based cropping systems

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Introduction

Coconut, arecanut and cocoa are grown as homestead crops as well as in organized plantations in Peninsular India. The perennial nature of the crops coupled with conducive cropping system in most cases provides an ideal niche for the build of several pest species. Biological methods of pest control using parasitoids, predators and pathogens play vital role in pest suppression of coconut palm and use of chemical pesticides are minimum resorted to. Crop Habitat manipulation like shade regulation, pest repulsive intercrops and field sanitation are important aspects in IPM in coconut based cropping system.

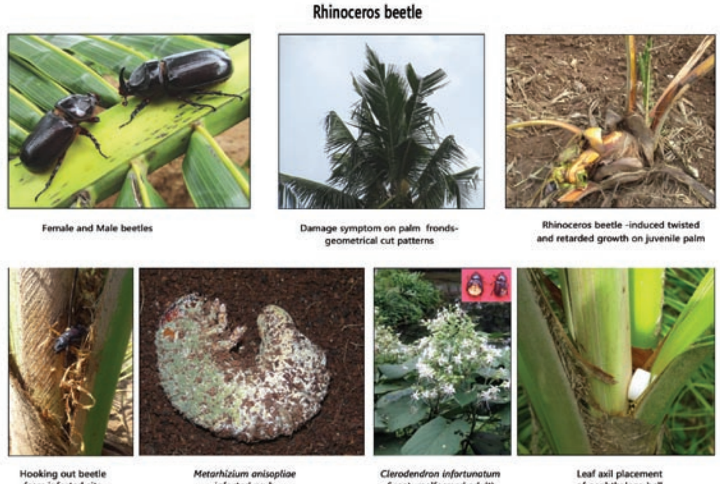
Rhinoceros beetle (*Oryctes rhinoceros* Linn.), red palm weevil (*Rhynchophorus ferrugineus* Oliv.), black headed caterpillar (*Opisina arenosella* Wlk.) nut infesting eriophyid mite (*Aceria guerreronis* Keifer) and white grub (*Leucopholis coneophora* Burm.) are the major pests of coconut enjoying wider distribution in all coconut growing tracts of India. Rodents also cause heavy crop loss in certain areas like Island ecosystem and lands locked with water bodies. Minor pests include coreid bug, slug caterpillars, scale insects, mealybugs, termites and whiteflies

a. Rhinoceros beetle (Oryctes rhinoceros Linn.)

Oryctes rhinoceros commonly known as rhinoceros beetle or black beetle is a major pest of coconut in all the coconut growing regions of the world. The beetle is a major pest of oil palm (*Elaeis guineensis*) and also infests other palm species like date palm (*Phoenix dactylifera*) and palmyrah (*Borassus flabellifer*) *etc.*

Damage and symptoms: The adult beetles cause damage to palms at all age groups by boring into the unopened spear leaves and spathes and chew off the soft internal tissues. As the pest bores deeper into the host it pushes out the chewed up tissues as fibres, which are seen extruding from the entry points. Once these injured spindles open up, the green leaves present a geometric 'V' shaped cut pattern. Attack in young seedlings results in stunted growth and delayed flowering. Black beetle infestation has to be considered serious as the damage done by this pest provides egg laying sites for another lethal pest *viz.*, red palm weevil and for entry of fungal pathogens.

Rhinoceros beetle



Female and Male beetles; Damage symptom on palm fronds- geometrical cut patterns; Rhinoceros beetle -induced twisted and retarded growth on juvenile palm; Hooking out beetle from infested site; *Metarhizium anisopliae* infected grub; *Clerodendron infortunatum* (inset- malformed adult); Leaf axil placement of naphthalene ball

Bioecology: The adult is a stout black beetle 35-50 mm in length and 14-21 mm in breadth. It has a cephalic horn, which is longer in males. The beetle breeds in the decaying organic matter like cattle dung, compost pits, dead and decaying coconut logs, saw dust, coir pith, rotting paddy straw, sugarcane waste etc. The larvae are creamy white in colour with the body strongly arched dorsally. Grub period is about 130 days with three instars. The pupal period varies from 20-29 days. Adult longevity is 3 - 4 months. Adults are active during night and remain hidden during day time in the feeding or breeding sites.

Pest Management: Integrated Pest Management adopted on a community basis essential to bring an effective control of Rhinoceros beetle population. The components of IPM package are listed below.

Mechanical control: This method involves periodical examination of the palm, crown and extracting the adult beetles by menace of a beetle hook. During peak period of pest infestation (June – September).

Prophylactic control

- Application of oil cakes of neem (*Azadirachta indica*) or marotti (*Hydnocarpus wightiana*) in powder form @ 250 g. mixed with equal volume of sand in to the top most three leaf axils around the base of the spindle leaf during May, September and December is an effective prophylactic method against Rhinoceros beetle and Red Palm Weevil.
- Application of naphthalene balls in the leaf axils at the base of the spindle @ 12g. per palm covered with sand also provide good protection against the pest especially in young palms.
- Recently ICAR-CPCRI has developed a botanical soap based tablet and gel based product for repulsion and avoidance of feeding. Tablet can be placed on the top most three axils and paste can be swiped around the spear leaf

Biological control: This method is the most important component in the IPM of *O. rhinoceros* and in two microbial pathogens are employed for the control. Wide and successful control of *Oryctes rhinoceros* has been achieved using *Oryctes rhinoceros nudivirus* (OrNV) and *Metarhizium anisopliae*.

Oryctes rhinoceros nudivirus:

This virus gains entry in to the host only orally through contaminated food. All the three instars of the *Oryctes* grubs are infected As the virus multiply in the midgut epithelium, the fat body disintegrates and the haemolymph content increases. This causes translucency of the thoracic region, which is an important exopathological symptom for identification of the disease. In certain cases increased turgor pressure may cause extroversion of the rectum .On dissection, the midgut filled with white fluid is clearly seen in advanced infection stage. The infected grubs die within 15-20 days and do not pupate. The healthy grubs on the other hand are active and feed vigorously and remain in the lower part of the feed. Their thoracic region does not show translucency but show a dark midgut line showing the gut filled with feed. Giemsa staining (3%)

of the midgut fluid and its epithelial tissue for 45-60 min. show pink coloured enlarged nucleus with vacuoles under light microscope. In the advanced stage of infection dark pink colour ring is also observed around the nucleus of the infected cells. The viral particles are seen only under Electron Microscope. Adults become inactive lay less number of eggs (1-2 as compared to 108 eggs/female) and become short lived (25 days as compared to 142 days) than the healthy ones. The midgut of virus-infected beetle is filled with whitish colour fluid as in the grubs. Infected adults disseminate virus through their fecal matter into surroundings at the rate of 0.3mg virus/adult/day. The virus- infected cadavers or virus triturate could be stored at - 40^0C indefinitely.

Field dissemination: The best practical method of dissemination of this virus is by releasing the infected adults in the field @ 10-15 number/hectare

1. Allow 10-15 healthy adult rhinoceros beetles to crawl in a shallow glass trough containing the viral inoculums (1g midgut /100ml 0.001 PO_4 buffer at pH 7.0) for half an hour. The adult beetles can be collected using pheromone traps
2. Transfer the beetles in plastic boxes and starve them for 12-24 hours.
3. Release the beetles in the field preferably at dusk .The beetles disseminate the virus in to the surroundings through their excreta. Observe the field for rhinoceros beetle control once in six months.

Metarhizium anisopliae

This is also known as the “green muscardine fungus” and is pathogenic to all life stages of the *Oryctes rhinoceros*. It is very active during the monsoon when the relative humidity is high (90%) and the temperature is at the range of 26-28^oC. This fungus gains entry into the body of host through the cuticle region.

Effect on the host: There is loss of appetite in grubs, they become sluggish and ultimately after 12 to 15 days they die and get mummified. Few days later these mummified specimen becomes green in colour because of the production of spores externally.

Mass production of the fungus: The fungus can be cultured either in solid substrate, Cassava chips and rice bran mixture supplemented with nitrogen source, or by using sterilized coconut water. Using coconut water as the medium mass multiplication technique was developed in CPCRI. Coconut water supports better mycelial growth and sporulation of the fungus. The farmers themselves can adopt this method with some amount of training on the culturing of the fungus.

Field application: Spores @ $5x10^{11}$spores/m^3 of breeding area of *Oryctes* gives a successful establishment of this fungus. Once the fungus establishes itself, it will survive in the site for more than two years. The percentage of control of the pest is very high during the favourable season for the fungal growth

Treatment of breeding sites.

Restricting and managing the breeding sites could check the proliferation of the pest. Proper disposal of breeding grounds and field sanitation are important step steps in IPM of *Oryctes*. Incorporation of the weed plant *Clerodentron infortunatum* Linn. in the compost pit is suggested as cheap and effective method for managing *Oryctes rhinoceros* in the breeding grounds as the principles contained in the plant arrests the development of different stage of the pest.

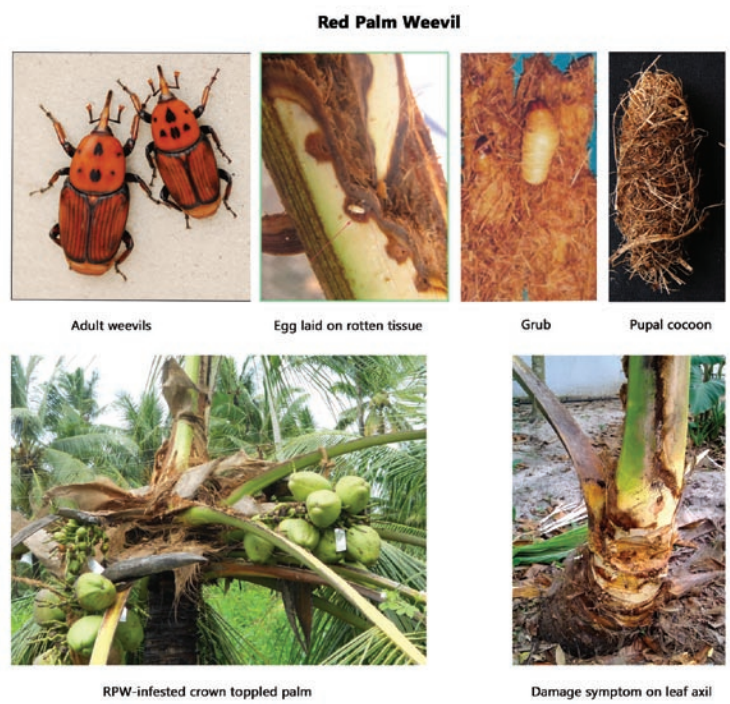
Pheromone traps

Specially designed PVC tube trap employing synthetic pheromone ethyl 4-methyl-octonate was found quite feasible for trapping black beetles in good numbers. This can be employed as one of the components in IPM in community based pest management approach with close monitoring. While placing traps in the field, plantations with juvenile palms have to be avoided.

b. Red palm weevil (Rhynchophorus ferrugineus Olivier)

Red palm weevil (RPW), a concealed tissue borer is the lethal pest of palms and is reported to attack 17 palm species worldwide. It is one of the key pests of coconut causing mortality of young palms to the tune of 1-3% in different tracts of country.

it enjoys a wide distribution in all coconut growing tracts of India. Young and dwarf palms are more susceptible to the pest infestation. Incidence of red palm weevil is relatively high in those areas having high incidence of rhinoceros beetle, bud rot disease and leaf rot disease. Shallow methods of planting and mechanical injuries on the palms also pave way for the pest attack. High multiplication rate of the pest coupled with continuous egg laying throughout the year hinders effective management of the pest.



Bioecology: The adult red palm weevil is medium sized measuring 35 mm long and 20mm wide with ferruginous brown colour. Snout is elongated and the dorsal apical half of the rostrum in males are covered with a tuft of brown hairs, where as rostrum is females are bare and longer. Mean fecundity is 275 eggs/female. the creamy white oval eggs are laid in small holes scooped out on soft tissues or on cuts , wounds or other decaying parts of the palm trunk/crown. even petiole cut ends act as oviposition sites. The odour of plant sap exuding from injuries or fermenting sell of fungal infections attract adult females for egg laying. Grubs of this internal tissue borer feed on the soft tissues of the palm crown. The full grown grub is stout, fleshy, apodous, body bulged in the middle and creamy white in colour with a brownish black head. Larval period is the destructive phase and lasts for 55-60 days. The weevil takes about 3-6 months for completion of the life stages from egg to adult depending up on weather conditions and type of food source. The adults have a prolonged life span extending up to 76 to 133 days .

Damage: Being an internal tissue feeder with all the life stages inside the palm tissues, it is very difficult to detect the pest attack during early stages. Wilting of central spindle, presence of chewed up fibres in the leaf axils, presence of holes in the crown or soft trunk portion with oozing out of a brown viscous fluid, splitting of leaf bases and gnawing sound produced by feeding grubs enable the detection of pest infestation *etc.* are characteristic symptoms of pest attack. Severe infestation results in toppling of the crown.

Pest Management: IPM for managing red palm weevil comprises the following important components *viz*., phytosanitation, prophylactic treatments, curative chemical treatments and pheromone trapping. Coconut palms dead due to red palm weevil and retained in the field serve as ideal source of inoculum for further build up of the pest in the field. Hence, the importance of field sanitation is very important to protect the palms. The pest is attracted to kairomones emanating from fresh injuries inflicted on the palms. Due to mechanical farm operations such as ploughing, cutting of steps for climbing the palms, the injured palm becomes more susceptible to weevil infestation. Timely treatment of wounds or injuries is unavoidable to ward off pest infestation.

New molecules viz., , imidacloprid @ 0.02%, Spinosad @ 0.013% and Indoxacarb @ 0.04% were promising for curative treatment and have given more than 80% recovery of infested palms. With the synthesis and availability of ferrugineol based pheromone lure for RPW, the IPM programme was modified to incorporate pheromone traps and it was successfully utilized to combat the pest in coconut and date palm which have proved that trapping of red palm weevil using pheromone lures (4-methyl 5-nonanone (Ferrugineone) and 4-methyl 5-nonanol (Ferrugineol) in food baited bucket traps can be one of the effective IPM tools when adopted in community level to manage red palm weevil provided all the precautionary steps involved in the use of pheromone traps are meticulously followed by the user. Efficacy and synergistic interaction of entomopathogenic nematode, *Heterorhabditis indica* (1500 IJ) with imidacloprid (0.002%) against red palm weevil grubs was reported.

c. Black headed caterpillar (Opisina arenosella Walker)

The black headed caterpillar, *Opisina arenosella* Walker (Lepidoptera: Oecophoridae) is a serious defoliator pest of coconut in India and Sri Lanka.

Bioecology: The adult moth is 10-15 mm long, 20-25 mm wide (wing expanded) and ash grey in colour. The male is smaller in size, with a slender abdomen ending in a short brush of scales, while in the females the abdomen is stouter and pointed towards the tip. Eggs are laid on the lower surface of leaflets near old larval galleries. Adult moth lays on an average of 137 eggs. Larval body is cylindrical, slightly compressed with a tapering hind end with three longitudinal reddish brown stripes dorsally and with the black head. Average larval period is 42 days and total life cycle from egg to adult takes about 8-10 weeks. The adult moths live for about 5-7 days.

Damage: First noticeable symptom of infestation is the drying of leaflets in patches. The caterpillars are voracious feeders and feed on the chlorophyll containing leaf tissues leaving the thin upper epidermis. They live in galleries made up of silken webs with scraped leaf bits and excreta on the lower side of leaves. The affected portions get dried and form conspicuous grey patches on the upper surface of the leaves. Usually the feeding and drying starts from the outer whorl of leaves and proceeds inwards. Close examination of leaflets shows presence of larval galleries on the lower side with live or dead stages of the pest. Severe pest damage results in complete drying of middle to inner whorl of leaves also. As the palms succumb to heavy loss by the non-functioning of affected leaves a crop loss of up to 45% in terms of nut yield was recorded from infested palms in the succeeding year of severe pest incidence apart from rendering the leaves unsuitable for thatching and other purposes.

Pest Management: Biological method of pest suppression has been accepted as a long term strategy to curb the pest problem in this perennial crop on account of increasing ill effects by the use of chemical methods for pest management. Parasitoids and predators play an important role in the natural biological suppression of *O. arenosella*. As the perennial nature of the crop permits a continuous interaction between the natural enemy and the pest without ecological upheavals, bio intensive-IPM has been recommended against coconut black headed caterpillar.

The larval parasitoid *Goniozus nephantidis* (Bethylidae) is released if the pest is at 3rd larval stage or above @ 20 parasitoid /palm and *Bracon brevicornis* (Braconidae) @30 parasitoid/palm at monthly intervals. The pre-pupal parasitoid, *Elasmus nephantidis* Rohw. (Elasmidae) and the pupal parasitoid *Brachymeria nosatoi* Habu.(Chalcididae) are also very effective in managing the pest. They are released @ 49 and 32% respectively for every 100 pre-pupae, pupae estimated to be present on the palm. Feeding the parasitoids with honey and exposing the newly emerged parasitoids to the host odours (smell of the volatiles of the injured *O. arenosella* larvae and gallery volatiles) is found to improve the host searching efficiency of *G. nephantidis.* Cutting and burning the heavily infested and fully dried outermost 2-3 leaves removes the pupae and other life stages of the pest. Insect and spider predators are abundant in the coconut ecosystem. The dominant insect predators are the carabid beetles *Parena nigrolineata*, *Calleida splendidula*; anthocoreid *Cardiastethus exiguus*, Chrysopids A*nkylopteryx* sp. *Chrysopa sp, etc*. A total of 26 species of spiders are recorded with the pest of which *Rhena*, *Sparassus* and *Cheiracanthium* are the major predators. Predatory ants also play major role in population reduction of *O. arenosella* in the field. Nutritional management of the palm with balanced dose of recommended fertilizers and proper irrigation to rejuvenate the pest affected palms are essentially required to regain the yield potential of pest infested palms.

d. Nut infesting eriophyid mite (Aceria guerreronis Keifer)

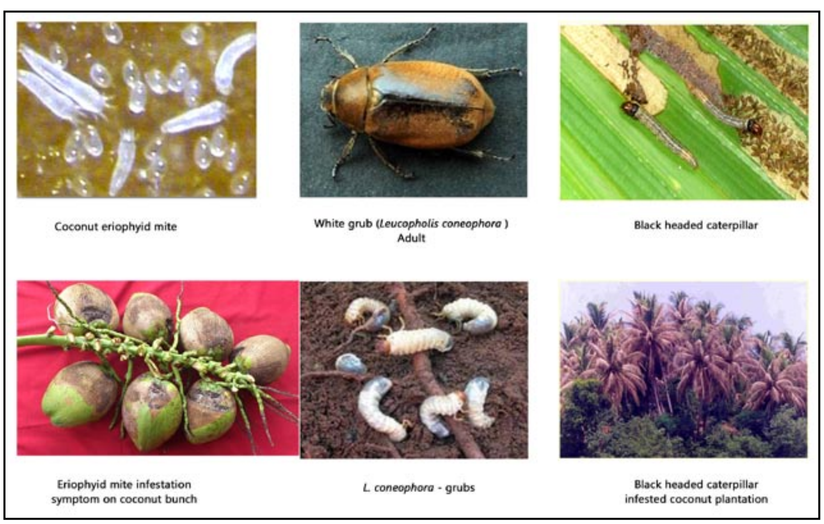
Bioecology: Coconut mite is a microscopic creamy white, vermiform organism measuring 200-250 microns in length and 36-52 microns in breadth. The body is elongated, cylindrical, finely ringed and bears two pairs of legs at the anterior end. Mites attain sexual maturity within a week's time and start laying eggs. An adult mite lays about 100-150 eggs. The total life cycle is completed in 7-10 days. Coconut buttons of third and fourth bunches harbour maximum mite population. The pest activity has been observed throughout the year with the population peak during the summer months.

Damage: The mite infestation symptoms are observed approximately one month after the initial colonization of the mite inside the fertilized buttons. Appearance of elongated white streaks below the perianth is the first external visual symptom on young buttons. In many cases, an yellow halo develops around the perianth. Within a few days this halo develops into yellow triangular patch pointing towards the distal end of the button. This can be clearly seen in 2-3 month old buttons. In a short time the yellow patch turns into brown and show necrotic patches on the periphery of the perianth. As the nut grows the injuries form warting and longitudinal fissures on the nut surface. In severe infestation the husk develops cracks, cuts and gummosis. Shedding of buttons and young nuts and malformation of nuts as a result of retarded growth are the other indications associated with severe attack of the pest.

Pest Management: Owing to the concern over environment contamination by repeated chemical pesticides application, currently botanical pesticides *viz*., neem based biopesticides are recommended for management of the pest in the field. Spraying of neemoil-garlic soap mixture at 2% or commercial botanical pesticides containing azadirachtin 10,000 ppm @ 0.004% or root feeding with neem formulations containing azadirachtin 50,000 ppm (7.5 ml) or azadirachtin 10,000 ppm (10 ml) mixed with equal volume of water is recommended for mite management.

Presently, emphasis is given for development of biocontrol strategies as they are safe and ecofriendly and vital in sustainable management of the pest. The fungal pathogen, *Hirsutella thompsonii* has received considerable attention throughout the world as the most effective natural enemy of eriophyid mite of coconut. Conservation of the predatory fauna in the ecosystem is beneficial to regulate the coconut mite in nature.

The nutritional status of the palm plays a significant role in the management of the pests. The nutrient management package consists of balanced application of NPK fertilizers at recommended doses in two splits (Urea 1.0 kg, rock phosphate 1.5 kg, muriate of potash 2.0 kg), recycling of organic biomass in coconut ecosystem using *in situ* vermi composting or growing of green manure crops like cow pea or sunnhemp and its incorporation in coconut basin and conservation of soil moisture by appropriate mulching methods.



Coconut eriophyid mite

White grub (*Leucopholis coneophora*) Adult

Black headed caterpillar

Eriophyid mite infestation symptom on coconut bunch

L. coneophora - grubs

Black headed caterpillar infested coconut plantation

e. White grub (Leucopholis coneophora Burm.)

White grubs are major pests of coconut palm mostly found in sandy loam soil tracts of Kerala and Karnataka. Grubs are polyphagous and feed on roots of coconut palm as well as other intercrops like tubers, rhizomes, vegetables *etc*.

Bioecology: Adult beetles are chestnut brown coloured and they emerge out of soil after pre-monsoon showers in May-June. Adult emergence from soil was observed in the field after 4-5 rainy days combined with a sudden fall in soil temperature, which invariably begins after sunset and completes within half an hour. Eggs are laid in soil and the hatched out grubs feed on the root of coconut and intercrops. Average fecundity is 23 eggs. Incubation period is 24 days and the I, II and III larval stages were completed in 40, 55, and 175 days respectively followed by pupal period of 25 days. Grubs are creamy white in colour with a brown head. Pest completes its life cycle in 300-310 days.

Damage: In nursery seedlings the grubs feed on tender roots and also tunnel into the bole and collar regions resulting in the drying of the spindle leaves followed by gradual death of the seedlings. In older coconut plantations continuous infestations by the grubs results in yellowing of leaves, premature nut fall, delayed flowering, retardation of growth and reduction in yield. Peak grub population is seen in the coconut basin during September-October

Pest Management

- Hand picking and destruction of adult beetles during emergence period (May/ June)
- Soil application of bifenthrin @ 2 kg ai / ha (bifenthrin 10 EC @ 20 litres ha^{-1} in 500 l of water) when first instar stage of grubs dominate in the field (July-August)
- Root zone application of entomopathogenic nematode, *Steinernema carpocapse* @ 1.5 billion IJs / ha and imidacloprid 17.8 SL @ 0.25 ml / litre during September-October. Need based repeated application of EPN.
- Regular ploughing to expose the grubs to predators

f. Coreid bug: Paradasynus rostratus Dist.

The widespread occurrence of the coreid bug, *Paradasynus rostratus* Dist. (Heteroptera: Coreidae) was reported as a serious emerging pest on coconut from Southern districts of Kerala. The bug causes heavy crop loss by shedding of developing buttons and immature nuts. .

Bioecology: Adults are brown or chocolate brown in colour with a body size of 2 cm in length and 0.5 cm width. Female bugs lay eggs in clusters of 4-5 rows closely apposed end to end on leaf petiole, spathe, spadix or young nuts. On an average 54 eggs are laid by a bug. The freshly laid eggs which are oval shaped with a yellowish tinge turn into reddish color with golden tinge just before emergence of nymph. The nymphs emerge out within 8-10 days. Total nymphal period which includes five-instars is completed within 30 days. The newly hatched adults can be seen on the new inflorescence and young bunches.

Coreid bug infested coconut

Damage: Nymphs as well as adults feed on female flowers and tender nuts. While feeding, the saliva is injected into the feeding site through the proboscis and the toxin present in the saliva damaged the tissues around the feeding site. These feeding punctures develop into necrotic lesions and these eye-like depressions can be clearly seen if the perianth of the shed button is removed. When female flowers are attacked prior to pollination such flowers get dried and can be seen attached to inflorescence on the crown resulting in production of barren buttons. Most of the infested buttons and tender nuts shed down. The retained nuts on the bunches develop furrows and crinkles on their husks and are malformed. In many cases gummosis can be seen on such nuts. In severe infestation, the kernel of infested nuts become thin, malformed and cannot be used for edible purposes. Guava, cashew, cocoa, tamarind, anona and neem are alternate hosts of *P. rostratus.* Populations build up starts from first rainy period (last week of May or first week of June) and there is a steady increase in the population reaching a peak during October-December

Pest Management: Application of neem seed oil plus garlic emulsion 2% was found effective in the suppression of the pest. Spraying of azadirachtin 300 ppm @ 0.0004% (13 ml / L) reduced the pest incidence at the highest level. Two rounds of azadirachtin spray on young coconut bunches of 1-5 months old during May-June and September-October are quite essential for satisfactory control of the pest in the field. In gardens where coreid infestation persists a third round of spraying is recommended during December-January. Crown cleaning to destroy eggs and immature stages of the pest along with pesticide application on the affected young bunches is recommended for coreid bug management.

g. Scale insects, mealy bugs and whiteflies

In coconut, four species of armoured scales *viz., Aonidiella orientalis, Aspidiotus destructor, Lepidosaphes megregori, Chionaspis* sp. were recorded from Kerala and Minicoy. Three species of soft scales *viz., Ceroplastes floridensis, Coccus hesperidum, Vinsonia stellifera* were also observed on coconut from these regions.

Five species of mealybugs are associated with coconut in India. They are *Palmiculter palmarum, Pseudococcus longispinus, Pseudococcus cocotis, Dysmicoccus* sp. and *Rhizoecus* sp.

Pest Management: Destruction of highly infested plant parts at the initial stages of infestation and removal of alternate weed hosts in the immediate vicinity is practiced for pest management. As the pest is naturally suppressed by predators especially coccinellid beetles, conservation of them in the ecosystem is recommended. Scale insects are spread by transport of infested plants or plant parts. Surveillance should be strict on the movement of planting material to avoid spread of scale insects across the transcontinental borders. Plants need to be provided with good growing conditions and proper cultural care, especially appropriate irrigation so they are more resistant to scale damage. Healthy plants in well drained soils are seldom seriously infested. In case of out breaks, three sprays of 2.5% fish oil rosin soap were found to be effective in reducing the population of *A. destructor.*

h. The Rugose spiralling whitefly (RSW)

The Rugose spiralling whitefly (RSW) is an invasive pest on coconut reported from Pollachi (Tamil Nadu) and Palakkad (Kerala) during July-August 2016. Presence of sooty mould on upper leaf surface and the prevalence of active egg spirals and adult whiteflies on underside of leaves are the marked symptoms of infestation. Though the pest has been reported in different districts of Kerala, it has not caused any severe economic losses. It was observed that more than 50 % of the whitefly was parasitized naturally by the aphenilid parasitoid, *Encarsia guadeloupae* which is playing an important role in natural biosuppression of the pest. Use of insecticides is not a viable option for the management of whitefly as causes a reduction in the build of natural enemies, especially *E. guadeloupae*. Therefore, population build-up of natural enemies, either through biological control or introduction of parasitized pupae, would be a more feasible and sustainable alternative approach at this point of time for the long-term bio-suppression of RSW.

The integrated pest management strategies to be adopted are as follows:

1) Application of 1% starch on the sooty mould affected leaves to flake out the mould,

3) Fixing of an yellow sticky trap of one meter width painted with white grease or castor oil on the trunk of infested palms to trap the adult whiteflies.

4) In severe case, spraying neem oil 0.5% is recommended

RSW infested coconut leaflet

i. Rodents (Rattus rattus wroughtoni **Hinton)**

Damage: Typical rat damage to tender coconut consists of a small hole about 5 cm diametre near the stalk region. The rat after gnawing the husk consumes the inner contents including the soft shell of the nut and such damaged nuts usually remain on the bunch for a further period of 2-6 days. The fallen nuts are seen around the basin of the palm. Three to six months old tender nuts are mostly preferred by this mammalian pest.

Pest Management: Planting coconut seedlings in correct spacing as well as destruction of fallen fronds and other farm wastes at regular intervals would ward off the rat activity from coconut gardens. Wrapping the trunk of coconut trees using polythene sheets was found to reduce the damage by rats in Minicoy. In coconut plantations, the black rats generally live on the crowns of the coconut palm by constructing nests. Hence, removal of dried leaves, spathes and matrix regularly from the crowns expose the nesting placing of these rats to predators. A habitat alteration discourages rats from population build up on the crown.

The more effective and economic way of managing this pest is by the use of single dose anticoagulant rodenticide, Bromadiolone (0.005%) is wax cake formulation. In coconut, application of 10 g Bromadiolone (0.005%) blocks two times at an interval of 12 days on the crown of one tree out of every five trees is recommended for effective control of black rat. This method is highly cost-effective. If the damage is restricted to certain palms, only such palms require baiting.

Conclusion

Careful understanding of pests and its diagnostic symptoms are very crucial for successful implementation of pest management strategies in plantation crops. A holistic approach in the execution of IPM with greater emphasis on pest-defender relationship and crop-habitat diversification strategies are the need of the hour. Adequate and timely nutrition of crops with need-based irrigation are very essential components in the field level suppression of pests. Farmers field school and farmer participatory approaches in pest management have emerged as effective tools in pest management. Impact of climate change and transformation of minor pests as key pests need to be closely scrutinized. Crop production and protection systems should therefore work in synergy for realizing highest returns from plantation crops farming.

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Integrated Disease Management in coconut based cropping systems

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The Coconut palm (*Cocos nucifera L.*) belonging to the Monocot Family Arecaceae, grown in the tropical humid areas in over 90 Countries in the World, suffers from a number of biotic and abiotic stresses. This palm is affected by a number of diseases from its germination onwards, some of which are lethal while others cause economic loss by reducing the quality/quantity of nut yield. Microbial pathogens including fungi, bacteria, viruses, viroids, and phytoplasmas are known to cause various diseases in coconut palms. Coconut, although being grown by many farmers as a monocrop, it is always recommended that spaces and light available in the coconut orchards should be fully utilized by growing appropriate inter crops. Although production and productivity of coconut in India has grown up considerably in the past few decades, prevalence of pests and diseases in majority of the coconut areas in the country has adversely affected the coconut industry to a large extent. The palm is susceptible to a number of diseases and pests. Some of them are fatal while others reduce its vigour and finally resulting in economic loss. Eight hundred and thirty insects and mites, 173 fungi and 78 species of nematodes have been found to be associated with coconut. Coconut palm, being a perennial crop, provides continuous supply of food and shelter for the build-up of various pests and diseases, which cause extensive damage to the crop during all stages of its growth. Constantly changing cropping systems and adoption of agro-technologies for higher productivity without looking into the ecological balance of the nature resulted in instability in biotic and abiotic components of the ecosystem. Such disruptions have created instances of minor pests emerging as major pests and also resulted in large scale spread of major pests to newer areas. In India, the plant health management strategies in coconut were initially developed with more orientation towards use of insecticides and fungicides. But increased awareness on the side effects caused by indiscriminate use of plant protection chemicals had made integrated pest and disease management (IPDM) the need of the present era. Diagnostic symptoms and integrated management of important diseases of coconut are briefed here. Adoption of appropriate and economically viable management practices compatible with the farming system will help in enhancing the profitability and sustainability.

A. Fungal diseases

1. Bud rot

Occurrence and distribution: Bud rot of coconut was first noticed in Grand Cayman in 1834. Since then, the disease has been reported from every coconut producing region of the world. In

India, bud rot was reported by Butler in 1906. It occurs commonly in west and east coasts of India. The disease is sporadic in nature in most of the places; however, outbreaks of epidemics are also common in certain areas. Bud rot causes considerable economic loss to the coconut cultivators in Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Bud rot incidence is also noticed in other states like Maharashtra, Goa and Madhya Pradesh. The intensity of the disease is increasing year after year in the southern part of India with the inoculum buildup in the endemic areas leading to heavy economic loss to the coconut growers.

Diagnostic symptoms: Withering of the spindle leaf marked by a pale colour is the primary visible symptom of the disease(Fig.1a). The affected spindle leaf turns brown, hangs down and can easily be pulled out as the basal portion of the spindle is completely rotten emitting a foul smell. Subsequently, younger leaves next to the spindle also fall away one by one leaving only outer whorl of matured leaves in the crown (Fig.1b,c). Ultimately, the palm succumbs to the disease with the death of the growing bud. The bud rot pathogen also causes water soaked lesions on nuts, quite independent of bud rot, and nut fall.

Fig.1.Bud rot. a) Whithering of spindle leaf, b) Death of growing bud, c) Severe incidence of bud rot.

Causal organism: Different species of *Phytophthora* has been reported as the causal organism of bud rot from various countries. In India, this disease has been reported to be mainly caused by *Phytophthorapalmivora* Butl.

Epidemiology: Relative humidity and temperature plays an important role in the bud rot incidence and spread. Extended period of relative humidity and prevalence of cooler temperatures are congenial for bud rot incidence. Rainfall aggravates infection and young palms are more susceptible. A minimum temperature of 21-24°C and relative humidity of 97-100 % are optimum for the incidence of disease. Disease development is determined by the duration of such favourable days. Bud rot disease is favoured by continuous high rainfall. Low lying areas and plantations with a very dense stand favours maintenance of high relative humidity, which in turn results in increased disease incidence. The disease incidence is also high in hilly tracts where cooler temperatures coupled with very high relative humidity prevail for extended periods in the coconut crown because of the high altitude of the place. Common slug, *Deroceras* species have been shown as possible vector in spread of *P.palmvivora* and shown that they feed heavily on mycelium (Fig.2a,b) and faceal matter contains sporangia and chlamydospores (Fig.2c). They climb the tall trees (Fig.3d).

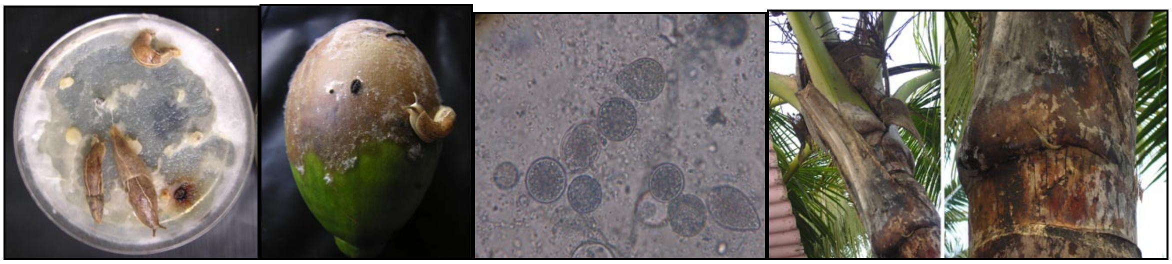

Fig.2.Feeding of mycelium of *P.palmivora* on culture(a), on coconut(b), propagules in faceal matter of slug(c) and reaching the tree top (d) by slug.

Disease management: Bud rot disease can be effectively managed by adopting integrated management practices.

*Host resistance***:** Dwarf palms are more sensitive to bud rot disease. In Asia, local ecotypes are generally more tolerant to *P. palmivora* than introduced ecotypes. Preliminary studies conducted in India using detached leaves of different coconut cultivars revealed that Philippine ordinary is highly susceptible followed by West Coast Tall among the tall cultivars. Among the dwarf varieties, Chowghat Orange Dwarf has been reported to be more susceptible to *Phytophthora* infection.

Cultural practices: Improved drainage and wider spacing will help in reducing the relative humidity. Field sanitation would reduce the inoculum build up in the plantations and check the spread of the disease. Rotten portion of the crown should be destroyed. In advanced stages of infection, the diseased palm should be removed and replant with good quality coconut seedlings, wherever sufficient space is available.

Prophylactic treatment: It is important to give prophylactic treatment to all palms in disease endemic areas before the onset of monsoon by spraying 1% Bordeaux mixture. In certain dwarf palms, phytotoxic symptoms like brown sunken spots followed by nut shedding have been observed when Bordeaux mixture is sprayed. In such palms, crown cleaning followed by pouring of mancozeb solution (5g in 300 ml water /palm) around the base of the spindle and placement of perforated sachets containing mancozeb (2 sachets/palm; 5 g mancozeb/sachet) in the inner most leaf axils before the onset of monsoon is a very effective prophylactic treatment

Curative treatment: Curative measures have to be adopted when the spindle has just started showing symptoms of withering.

- In the early stage of the disease, remove the spindle leaf by pulling it out and cut and remove the infected tissues completely.
- Two or three healthy leaves adjacent to the spindle may have to be removed if necessary for easy removal of all rotten portions and thorough crown cleaning.

- The wound should be treated with Bordeaux paste 10 % or mancozeb solution (5g in 300 ml water /palm) along with placement of sachets containing mancozeb (2 sachets/palm; 5 g mancozeb/sachet) in the inner most leaf axils for giving extended protection. The treated wound should be covered with polythene cover to prevent entry of rain water and this protective covering should be retained till normal shoot emerges.
- The diseased tissues should be burnt after their removal.

Nutrient management: Besides integrated disease management techniques, nutrient management practices for the affected palms as well as healthy palms are also important for improving the health and vigour of the palms for higher yield.

Pest management: Rhinoceros beetle attack predisposes the palm to bud rot infection (Fig.4b) Hence prophylactic measures to prevent beetle infestation have to be undertaken in bud rot endemic areas.

2. Leaf rot

Leaf rot is the major fungal disease of coconut in root (wilt) disease endemic areas. The disease is prevalent in root (wilt) disease affected tracts of India and Sri Lanka. The disease is rampantly distributed in southern districts of Kerala state. It is also observed in root (wilt) disease affected tracts in Tamil Nadu. About 65 % of root (wilt) diseased palms are super imposed with leaf rot disease. Normally farmers identify a palm as root (wilt) affected only when the leaf rot sets in.The disease causes drastic reduction in photosynthetic area, resulting reduction in yield.

Diagnostic symptoms: Leaf rot symptoms initially appear as minute water soaked reddish brown lesions on the spindle leaves (Fig.3a). These lesions enlarge, coalesce freely resulting in extensive rotting. If the leaf rot infection happens in the early period of spindle leaf emergence, expansion of lesions would be rapid and the rotting may progress to the interior of the spindle also. Often the tips of the rotten leaflets of the spindle stick together while the bases of the leaflets are open. The rotten portion of leaflets dry up, turns black and shriveled and may fall off leaving the midrib alone(Fig.3c).

Fig.3. Leaf rot ,a) reddish brown symptoms, b) rotting of spindle leaves, c) leaf rot on root (wilt) affected palm.

Leaf rot is a fungal disease complex caused mainly by *Colletotrichum gloeosporioides*,*Exserohilum rostratum* and *Fusarium solani*.The cultures of *C. gloeosporioides* exhibit sparse, cottony, white to pale grey mycelium with bright orange conidial masses produced in concentric rings on the colonies

Leaf rot is an air borne disease. Weather factors play an important role in disease intensity and spread. The disease incidence is high during monsoon season with high humidity (> 90%) and optimum temperature (28°C). The population of pathogenic fungi is also influenced by weather parameters. Maximum population of *C. gloeosporioides* occurs during monsoon months(June-September), whereas, *Fusarium* spp. is the common pathogen during dry season (January- April).

Disease management

Integrated strategies: The integration of leaf rot management with pest management and general cultivation practices is very effective in improving the health of the palms and thereby increasing the yield.

- Cut and remove rotten portions of the spindle and the adjacent two innermost fully opened leaves. By pruning of affected portions, the fungal inoculum load in the crown can be reduced.
- Mix hexaconazole(2 ml) or mancozeb(3 g) in 300ml water and pour around the base of the spindle leaf or apply talc based formulation of *Pseudomonas fluorescens* or *Bacillus subtilis* singly or in consortium @ 50 g in 500 ml/ palm.
- Undertake prophylactic measures to prevent rhinoceros beetle attack.

3. Stem bleeding

The stem bleeding disease of coconut palm has been reported from Sri Lanka, India, Philippines, Malaysia, Trinidad, Florida, Papua New guinea, Fiji, Ghana, West Indies, Brazil, Indonesia and China. In India, the disease is prevalent in almost all coconut growing tracts.

Diagnostic symptoms: The characteristic symptom is the exudation of reddish brown fluid from the cracks, mostly at the basal part of the trunk (Fig.4). The tissues beneath the lesions show decay. As the disease progresses, more area underneath the bark gets decayed, the lesions spread and coalesce to form large patches (Fig.4). The exudates dry up and turn a black crust. The trunk gradually tapers towards the apex. In the advanced stage, the vigour of the tree is affected resulting in reduction in crown size and nut yield. The tree is not killed but become uneconomical to maintain. In extreme cases, the trees may become barren and die. In advanced stages of the disease, infestation with *Diocalandra stigaticollis* weevil can be seen, which hastens the deterioration of the palms.

Fig.4 Stem bleeding disease, a) exudation of reddish brown fluid from the cracks, b) Tissue decay,c) Conidia of *Thielaviopsis paradoxa*

Thielaviopsis paradoxa (de Seynes) von Hohnel is the incitant of stem bleeding disease of coconut. *T. paradoxa* is pathogenic to a number of economically important crops *viz*., oil palm, arecanut, date palm, sugarcane, pineapple and ornamental palms. The fungus is a weak pathogen and enters the trunk through wounds/growth cracks. Sudden heavy rains following prolonged dry period or heavy manuring favour the development of growth cracks. Trash burning near the base of the palm has also been found to cause damage to the trunk. Poor drainage, formation of hard laterite pan leading to crippled root growth, imbalanced mineral nutrition or other physiological disorders are other predisposing factors. Climatic factors also could play a role in symptom expression. From inoculation studies, it has been found that the progress of the disease was faster during months of high humidity(July- November) and congenial temperature. Coconut varieties *viz.*, Banawali Green Round, Banawali Brown Round and Malayan Orange Dwarf are less susceptible to *T. paradoxa* based on detached petiole technique, while Malayan Green Dwarf, Chowghat Orange Dwarf and Philippines Ordinary are more susceptible.

Integrated strategies: The disease can be effectively managed if control measures are adopted in early stages of infection.

- Remove affected bark tissues with a chisel and apply hot coal tar to protect the wound and destroy the chiseled tissues by burning or apply a paste of talc based formulation of *Trichoderma harzianum* on the bleeding patches on the trunk.
- Apply *T.harzianum* enriched neem cake 5 kg per palm in the basin every year during September- October.
- Summer irrigation improves the health of the palm as well as yield.
- Since wounds on the trunks predispose the palms to infection, any type of wound on palms is to be avoided. Care should be taken not to injure the stem base while ploughing the garden with tractor.

4. Basal stem rot

This disease has been reported from India, Sri Lanka and other coconut growing countries. In Tamil Nadu, this disease was first observed in Thanjavur district in 1952 and hence called ‘Thanjavur wilt’. In Karnataka, it is known by the popular name ‘Anabe roga’ and in Andhra Pradesh, ‘Ganoderma wilt’. In Andhra Pradesh, the disease is mainly prevalent in lighter soils in the coastal districts than in heavy soils. Wide spread occurrence of the disease is noticed in the maidan tracts of Karnataka especially in sandy soils. Sporadic occurrence of the disease is noticed in some tracts of Kerala, Maharashtra and Gujarat states also.

*Diagnostic symptoms***:** The initial symptom of the disease is decay and death of the fine roots. The characteristic symptom of the disease is extensive rotting and discolouration of root system. In severely diseased palms, more than 70 % root rotting is observed. From bole region the infection progresses to the basal portion of the stem. The first visible above ground symptom of the disease is exudation of reddish brown viscous fluid from the basal portions of the trunk of the affected palm(Fig.5). As disease progresses, bleeding patches extend up to three metres from the base of the palm. In advanced stages, basal portion of the stem decays completely. Occasionally, some infected palms do not show bleeding symptoms. In some palms, the bark from the base of the stem peels off. Fruiting bodies of *Ganoderma lucidum* appear at the base of the trunk in some palms just above the soil level prior to wilting or after the death of the palm(Fig.5). Crown symptoms include wilting of leaflets, yellowing followed by drying and drooping of leaves in the outer whorls of leaves(Fig.5).The spindle leaf and surrounding two or three young leaves will remain erect and healthy. Ultimately, all the leaves droop and fall off leaving the decapitated stem. There will be heavy button shedding. The affected palms produce barren nuts. The decapitated stem shrivels and dries up. The time taken from the initial appearance of bleeding patches in the stem to the death of the palms is from 6 months to 54 months, the average being 24 months. Trunk infestation with the scolytid beetle, *Xyleborus perforans* and the weevil, *Diocalandra stigaticollis* accelerate the death of the palm.

Fig.5 Basal stem rot, a) exudation of reddish brown viscous fluid from the basal portions of the trunk wilting of leaflets, b) yellowing of leaflets, c) wilting, drying and drooping of leaves in the outer whorls of leaves, d) Fruiting bodies of *Ganoderma.*

The disease is caused by *Ganoderma applanatum* and *G.lucidum.Ganoderma*, Plant hosts belonging to 19 families, 36 genera and 48 species have been reported to be affected by the pathogen. For detecting the presence of *G.lucidum* inoculum in coconut plantations, various plant speciessuch as Subabul *(Leucaena leucocephala)* and *Glyricidia maculata* can be used as indicator plants since these plants showed natural infection under field conditions at least six months earlier to infection on coconut palms. The disease is generally observed in sandy or sandy loam soils in coastal areas in the east coast where coconut is grown under rainfed conditions and also in neglected plantations. Soil moisture stress experienced during summer months, water stagnation during rainy seasons, presence of old infected stumps in the garden and non-adoption of recommended cultural practices favour the spread of the disease. Presence of hard pan formation in the sub-soil impedes root penetration, which in turn predisposes the coconut palms to infection. In the wilt endemic area of Thambikkottai of Thanjavur district, Tamil Nadu, the disease incidence is more between March and August. It is directly related with mean maximum soil temperature. Soil moisture at 5, 15 and 30 cm depths had a negative correlation with disease severity. The linear spread of the disease is more during December to May compared to the spread during June to November.

Disease management: The disease can be effectively contained by an integrated approach with cultural, chemical and biological methods as described below.

- Removal and burning of dead palms and palms in advanced stages of the disease including bole region and roots.
- Isolation of diseased palms from healthy palms by digging isolation trenches of 1 m deep and 30 cm wide.
- Regular basin irrigation during summer months or moisture conservation by coconut husk burial (250 husks/ palm).
- Avoiding flood irrigation or ploughing in infected gardens to prevent spread of the inoculum.
- Addition of 50 kg of farmyard manure and 5 kg neem cake per palm per year.
- Raising banana as intercrop, wherever irrigation is possible.
- Soil drenching with 1 % Bordeaux mixture thrice a year for one year or root feeding of propiconazole (1ml/l) in 100 ml of water thrice a year at quarterly interval. Fungicide treatments will be effective only for palms in early stages of the disease.
- If *Xyleborus* beetleattack is found in the stem, smearing with insecticide may be done.

5. Grey blight

Grey blight is a widespread disease of coconut in tropics especially in drought affected and neglected plantations. In India, the disease is very severe during summer months in low rainfall areas of Karnataka and Tamil Nadu states.

Diagnostic symptoms: Symptoms appear on the outer whorls of leaves as minute yellow spots with grey margin. Spots gradually turn brown with greyish white centre. Spots enlarge and coalesce causing extensive leaf blight. In advanced stages, complete drying and shriveling of the leaf blade occur giving a blighted or burnt appearance. The disease is caused by *Pestalotiopsis palmarum*.

Disease management

- Remove severely affected older leaves and burn.

- Spraying with Bordeaux mixture (1%) or propiconazole (0.025 %) or root feeding of Thiophanate-methyl or carbendazim (2.0g in 100ml of water).
- Follow recommended integrated nutrient management practices along with sufficient irrigation.

6. *Lasiodiplodia* leaf blight

Leaf blight is an emerging problem in Coimbatore, Erode, Dindigul, Tirunelveli and Kanyakumari districts of Tamil Nadu. Though leaf blight is present in coconut growing areas of other states of India, the disease is not a serious problem.

Symptoms: The disease appears on leaf and nuts. Affected leaflets start drying from the tip downwards and exhibit a burnt appearance. The leaves in lower 3 to 4 whorls are affected. Leaf blight induces apical necrosis of lower leaves with an inverted “V” shape, and symptoms similar to those induced by drought (water deficit) and other stresses. The leaflets have extensive necrotic lesions with defined edges and without transition areas between the necrotic and healthy tissues. The pathogen can internally colonize the rachis, inducing internal necrosis that moves upward toward the stem (systemic invasion). The necrotic tissues develop exposed cracks that release gums under the leaf rachis and at petiole insertion. On nut, small black sunken region appear near the perianth of immature nuts. The eryiophyid mite attacked nuts are infected by the pathogen and cause immature falling of nuts and rotting. When nearly mature /mature nuts were infected the infection spread internally into mesocarp without any external symptoms. The affected nuts are desiccated, shrunk, deformed and drop prematurely causing 10 to 25 % loss in nut yield.

B. Phytoplasmal diseases

1. Root (wilt) disease

Occurrence and distribution: Root (wilt) disease (RWD) was first observed in the erstwhile state of Travancore, presently the Kerala state during 1882. The disease was initially reported from three independent locations – Erattupetta area of Meenachil taluk, Kaviyoor and Kallooppara of Thiruvalla taluk and Kayangulam of Karthikapally taluk each at a distance of 50 km. Since then, the disease has spread to all directions. The disease is prevalent in a contiguous manner in all the eight southern districts of Kerala starting from Thiruvananthapuram to Thrissur and in isolated patches in the remaining 6 northern districts of the state. Apart from this, the disease is also prevalent in the districts of Tamil Nadu adjoining to Kerala State. The disease with symptoms similar to root (wilt) disease has been reported as ‘Weligama wilt’ in Sri Lanka.

Diagnostic symptoms: The most obvious and diagnostic symptom of the disease is the abnormal inward bending of the leaflets termed ribbing or flaccidity(Fig.7). Yellowing and marginal necrosis of leaflets are the other characteristic foliar symptoms associated with the disease(Fig.7). Rotting of roots, shedding of immature nuts, drying up of spathes and necrosis(Fig.7)of spikelets in unopened inflorescence are noticed in certain cases. The husk, kernel and oil of the nuts of the disease affected palms are of poor quality. Palms of all age groups are affected. The disease is non lethal, but debilitating. However, palms contracting the disease in the pre bearing age may not come to flowering and bearing.

Fig.7 Root (wilt), a)flaccidity, b)yellowing and marginal necrosis of leaflets, c)drying up of spathes and necrosis of spikelets in unopened inflorescence, d) advanced stage e) Phytoplasma

Causal organism: A phloem bound mollicute – phytoplasma belonging to 16SrRNA group XI has been identified as the cause of the disease.Presence of a pleiomorphic or filamentous shapeand is less than 1 μm in diameter in the phloem tissues by electron microscopy was reported to be the most reliable method for confirmation of phytoplasma in root (wilt) affected palms.

Epidemiology: The insects, lace bug (*Stephanitis typica*) and plant hopper (*Proutista moesta*)have been identified as vectors in transmitting the disease in nature based on histological, electron microscopy and field transmission trials. The coconut RWD has been found to occur on all soil types of Kerala under varying ecological conditions ranging from the high ranges of the Western Ghats to the coastal plains.

Vectors of root (wilt) disease, a)*Proutista moesta,* b)*Stephanitis typica*

Disease management

A complete control for phytoplasmal diseases are not yet available, but management strategies to reduce RWD intensity and rate of its spread were developed.One of the significant features of the disease is that it is not lethal but a debilitating malady which responds to ideal management practices. Two strategies, one for the heavily diseased contiguous area, and another for the mildly affected area have been formulated. Current methods include quarantine, sanitation, conventional plant protection measures such as application of pesticides, chemicals,use of resistant varieties, use of biological control and integrated nutrient management

Cultural practices: Cutting and removing palms with advanced disease and those that yield less than 10 nuts per palm per year; growing green manure crops – cowpea, sunhemp (*Crotalaria juncea*), *Mimosa invisa, Calapagonium mucanoides, Pueraria phaseoloides*, etc. which may be sown in coconut basins during April–May and incorporated during September– October; irrigating the coconut palms with at least 250l water per week; adopting suitable inter/mixed cropping in coconut gardens; providing adequate drainage facilities in coconut garden.

Nutrient management: Application of balanced fertilisers (applying balanced dose of chemical fertilisers, i.e. 500 g nitrogen (1.1 kg urea), 300 g phosphorus (1.7 kg mussouriphos), 1000 g potassium (1.7 kg muriate of potash)) in two splits – one-third during April–May and two-thirds during September–October under rainfed condition and in four splits during January, April, July and October under irrigated condition. In addition to this, 500 g MgO (1 kg magnesium sulphate) also has to be applied along with the second dose of fertiliser application.

Host resistance: The resistant/tolerant varieties,Kalparaksha (selection from Malayan Green Dwarf), Kalpasree (selection from Chowghat Green Dwarf) and the hybrid Kalpasankara (Chowghat Green Dwarf x West Coast Tall) identified by Central Plantation Crops Research Institute (CPCRI) are suitable for cultivation in RWD endemic tracts.

Varieties tolerant to root (wilt) disease, a) Kalpasree, b) Kalparaksha c)Kalpasankara.

2. Tatipaka disease

The disease is named after the village ‘Tatipaka’ in Andhra Pradesh, India where the disease was first noticed following a cyclone in 1949. The disease is endemic in east and west Godavari, Srikakulam, Nellore, Krishna and Guntur districts. Survey carried out during 1990 identified about 8179 coconut palms affected by Tatipaka disease in these districts.The disease is non lethal but of debilitating nature, generally affecting coconut palms in the age group of 20-60 years. Palms below 20 years of age are very rarely affected. Spread of the disease is not contiguous but sporadic at slow pace of 3.5 % over a period of five years

Symptoms: The disease affected coconut palms generally bear profusely for 2 to 3 years before the expression of foliar symptoms. With the onset of disease, there is a reduction both in number and size of leaves . The leaves exhibit characteristic chlorotic water soaked spots and the fronds bend abnormally sometimes twisting in loops. In the advanced stage there is a severe reduction in size of the crown. The leaves give a fascinated appearance due to improper unfolding of leaflets. The spathes produced are very small with very few rachilla. The bunches contain a mixture of normal and atrophied nuts (Fig19c). The atrophied nuts are barren with thinner spongy mesocarp with or without shell, copra and nut water. The undersized nuts show longitudinal cracks with occasional oozing of gummy exudates. In the advanced stages of the disease, the stem tapers, produces smaller spathes and inflorescence which ultimately do not bear any fruit.

Causal organism: Like root (wilt), initially the disease was considered as that of an uncertain etiology. The possible involvement of fungi, bacteria was ruled out since these microbes could not be isolated consistently form diseased palms. Sap transmission studies and electrophoresis of isolated DNA from the diseased palms ruled out the virus or viroid as the causal agent. Electron microscopic examination of tender roots, meristem, petioles of developing leaves and rachilla of tender inflorescence of diseased palms revealed the presence of phytoplasma in the sieve tubes Light microscopy with Dienes stain and fluorescence microscopy with aniline blue as fluorochrome also revealed the presence of phytoplasma in the diseased coconut palms.

Disease management: Since there is no prophylactic or curative measures for phytoplasma diseases, regular surveillance and removal of the diseased palms is recommended to arrest the further spread of the disease. Since the spread of the disease is very slow, removal of the affected palms has helped in eradication of the disease.

C. Threats of invasive diseases

1. Lethal Yellowing

Lethal yellowing (LY) is the single most important disease threatening coconut production worldwide. LY of coconut was first recorded in Grand Cayman Island in 1834 and Jamaica in 1884. Currently the LY is destroying the palms in Southern United States, Central America and Caribbean as well as west and east Africa. The disease caused by LY group phytoplasma is being known by different names in west Africa *viz* Cape St paul Wilt in Ghana, Kribi disease in Cameroon, Kaincope disease in Togo, Akwa disease in Nigeria. In east African countries like Tanzania, Kenya and Mozambique, it is known as 'lethal decline'. The symptoms of LY disease in coconut palms consist of essentially four stages. The symptoms lethal yellowing include premature nutfall with most of the nuts having a black or brown water-soaked area under the calyx, inflorescence necrosis, the yellowing of the oldest fronds and death of the bud and complete defoliation, leaving tree like telephone pole The coconut lethal yellowing group of phytoplasmas have been classified as being members of group 16SrIV. The cixiid, *Haplaxius* (*Myndus) crudus* was shown in transmission trials to be a vector of LY.

2. Coconut foliar decay or Vanuatu wilt

The coconut foliar decay is virus disease in Vanuatu. It is also known as foliar decay *Mindus taffini* or New Herbides coconut disease. Yellowing of a few leaflets on any of the fronds between position seven and 11 from the spear leaf is the first symptom. The yellowing spreads along the fronds, and the fronds break near the base so that they hang down through the still green lower leaves. When the younger leaves age, reaching positions seven to 11, they, too, turn yellow. The disease is caused by a very small circular single stranded DNA virus and which is named as *Coconut foliar decay virus* (CFDV, an unassigned species under family *Nanoviridae*). The virus occurs in the phloem of the coconut. Coconut is the only known host of the virus. Virus occurs in leaves, roots, embryo, trunks and even on the husk of the nut. Seed transmission is not yet established. The disease is transmitted by *Myndus taffini* Bonfils (Cixiidae).The disease is best controlled by either planting selected Vanuatu tall or the hybrid, Vanuatu Tall x Vanuatu Red Dwarf which are tolerant to the disease.

3. Cadang-cadang disease

Cadang cadang was reported fromsouthern Luzon in the Philippines in the early 1930s. This disease causing huge economic losses in coconut plantations in the Philippines. Newly developing nuts become more rounded and have equatorial scarifications at the initial stage of infection. Later, leaf spots begin to appear and inflorescences become stunted. Spathe, inflorescence and nut production decline and then cease. In the advanced stages of infection, more spots appear on the leaves and the fronds decline in size and number and the leaflets become brittle. Leaf spots coalesce, giving a general chlorosis. The crown size is reduced and later the palm dies. Usually, palms become naturally infected only after they have reached the age of flowering. In the rare cases where younger palms become infected, they are stunted and fail to produce inflorescences, although they survive well past the age of first flowering. It is caused by a small circular, single-stranded infectious RNA molecule that can replicate in the host cell and be transmitted independently of any other microorganism, referred to as the coconut cadang-cadang viroid**.** The mode of natural inoculation in the field is not known. No insect vector has been found. Positive transmission was obtained through assisted pollination of mother palms with pollen from diseased palms.At present, there is no control measure is available to control cadang-cadang. Strict enforcement of quarantine regulations by concernedgovernment agencies on the safe movement of coconutgermplasm from infected areas will prevent further spread ofcadang-cadang into disease-free areas.

Conclusion

Coconut being perennial crop is vulnerable for attack of one or other disease or pest throughout the year. Hence regular monitoring, timely application of prophylactic measures are very essential. Integrated plant and soil health health management involving IDM, INM, IWM and ICM need to be practiced to reduce the loss due to diseases in coconut.

Management of soil health in coconut based farming system using bio-inputs

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Coconut palm is a unique plantation crop cultivated in 2.1 million ha in India. The palm is at once a food crop, an oil-seed crop, a medicinal crop, an industrial crop, a horticultural crop, an ecological crop and most importantly a cultural crop that supports livelihood of more than 10 million Indians directly or indirectly. Its sustainability translates into sustainability of large swathes of humanity in coastal and hinterlands, Lakshadweep and Andaman and Nicobar islands of our country. The two main factors that challenge the sustainability of the coconut are the low national productivity as well as cyclical market economy. To address the first challenge, we at ICAR-CPCRI have developed several technologies/ bioinputs that can improve the soil and plant health and thereby enhance the productivity in ecologically sustainable manner. The technologies/ products developed are described below-

Bioinoculants

Bioinoculants are carrier-based preparations containing beneficial microorganisms in a viable state intended for seed or soil application and designed to improve soil fertility and help plant growth by increasing the number and biological activity of desired microorganisms in the root environment. Function-specific microbial groups such as nitrogen-fixers, phosphate solubilizers, plant growth promoting rhizobacteria (PGPR) and mycorrhizae are used as biofertilizers in coconut cultivation. These groups of microorganisms are responsible for nitrogen fixation, phosphate solubilization/phosphorus mobilization and production of plant growth promoting substances.

The microbial inoculants are prepared by formulating living cells of beneficial microorganisms in suitable carriers such as talc or sterilized vermicompost. Biofertilizers/beneficial microbial inoculants improve crop stand by producing and secreting plant growth promoting substances (phytohormones) such as auxins, gibberellins, cytokinins; by stimulating root metabolic activities using bacterial surface components; by stimulation of phytoalexins in roots; by phosphate solubilization, by reducing the soil pH by production of organic acids or other acidic substances; and/or by supplying biologically fixed nitrogen. Consequently, germination, root development, mineral nutrition and water utilization are improved.

Plant growth promoting rhizobacteria (PGPR) are important microbial resources for developing bioinoculants. They are known to possess multiple plant growth promotion properties. PGPRs also influence plant growth by indirect mechanisms such as suppression of bacterial, fungal and nematode pathogens by the production of various metabolites, by induced systemic resistance and/or by competing with the pathogen for nutrients or for colonization space.

Two PGPR based bioinoculants, '*Kera Probio*', a talc formulation of *Bacillus megaterium*, effective for raising robust coconut seedlings, and '*Cocoa Probio*', containing *Pseudomonas putida*, effective for raising healthy cocoa seedlings, have been developed at ICAR-CPCRI. Both these bioinoculants were also found to be effective for vegetable crops such as tomato, brinjal and chilli.

Similarly an Arbuscular Mycorrhizal bioinoculant, '*Ker*AM', has been developed at ICAR-CPCRI, which is a soil based AMF bioinoculant for coconut seedlings. The bioinoculant contains *Claroideoglomus etunicatum*, one of the dominant AM species isolated from coconut agro-ecosystem with high potential to increase the growth parameters of coconut seedlings.

***'Kera Probio'** and **'Cocoa Probio'** bioinoculant packets*

'*Ker*AM' bioinoculant packet

Coconut leaf vermicomposting technology

A substantial volume of recalcitrant biomass residue, in excess of 25 MT produced each year from this plantation crop that normally causes ecological and health issues, can be used in agriculture for rejuvenating soil health and fertility, increased crop production, enhanced economic benefits to resource poor farmers and for ecosystem sustainability through recycling technologies developed by us at ICAR-CPCRI.

The natural decomposition of organic by-products resulting from coconut cultivation and the nutrient release is very slow due to the presence of lignin and polyphenols in it. But earthworms, which survive only in organic matter, known as compost worms or manure worms can enhance the decomposition of such organic materials and mediate humus formation. A local strain of earthworm was identified at ICAR-CPCRI, related to African Night Crawler (*Eudrilus* sp.), which is quite efficient in converting coconut leaves into granular vermicompost. Subsequently, a technology for producing vermicompost from lignin rich and highly recalcitrant coconut leaf litter using this earthworm species was developed at ICAR-CPCRI. It converts coconut leaves into vermicompost in less than three months period and compost has C: N ratio of 10-17, 1.8 to 2.1 % N, 0.21 to 0.3 % P and 0.16 to 0.4 % K and organic carbon content of 18-20. As much as 4000 kg of good quality vermicompost can be produced from the wastes generated from 1 ha of healthy coconut garden every year by this earthworm that can meet a considerable percentage of nutrient need of the coconut palm. This technology has been considered as an important component of sustainable production technology for coconut. This vermicompost can also be used for improving the productivity of other annuals, vegetables, fruits, flowers as well as cash crops.

Large-scale coconut leaf vermicompost can be produced in pits, thatched sheds, open ground and cement tanks. However, the bed system of compost production carried out in cement tanks was found to be most efficient. The length and breadth of the tanks can be made as per convenience; but, the depth should be less than 1 metre.

Coconut leaves weathered for 2-3 months are to be used. After chopping off the thick base, the rest of the leaf can be put as such or in two pieces. Above this, a layer of cow dung slurry is spread. Three such layers can be accommodated in 1 metre deep cement tank. The ratio of coconut leaves to cow dung slurry is kept at 10: 1 (e.g. 1000 kg leaves: 100 kg cow dung slurry). Sufficient moisture must be ensured by sprinkling water regularly and the whole substrate is allowed to pre-decompose for 2-3 weeks. At the end of this period, 1000 worms per tonnes of substrate are introduced into the tank.

Depending upon the extent of weathering and pre-decomposition, a maximum of 70% of the substrate would be converted to vermicompost within a period of 60-75 days. Watering is stopped at this stage so that worms move to the bottom. Ready vermicompost can be collected from the top, shade dried and packed. Earthworms accumulated at the bottom can be used for next round of composting.

The indigenous earthworm *Eudrilus* sp. also has affinity for wastes other than coconut leaf wastes. A coconut garden, where other intercrops/ mixed crops are grown, generates leaf wastes from these intercrops also. All these mixture of wastes can be successfully composted using *Eudrilus* sp. earthworm. It has been found that coconut leaves can be mixed with pineapple waste, banana pseudo stem or gliricidia leaves in 3:1 ratio for effective utilization of other wastes commonly produced in coconut based cropping system.

Fallen dry Coconut leaves

Coconut leaf vermicompost

Vermicompost is a finely divided peat-like organic material with excellent structure, porosity, aeration, drainage and water holding capacity. It has appearance and many characteristics of peat. It can influence a number of soil physical, biological and chemical processes which have their bearing on plant growth, development and yield and is a better source of organic matter than other composts. Application of vermicompost improves the soil aggregation, aeration, and water holding capacity; root growth, microbial activity and the overall crop production capacity of the soil.

The vermicompost produced from coconut leaves using the technology developed at ICAR-CPCRI is now available by the trade name ‘Kalpa Organic gold’.

‘Kalpa Organic gold’

Coconut leaf vermiwash: liquid organic manure

Vermiwash (vermin-wash) is the clear brown coloured liquid collected after the passage of water through a column of actively vermicomposting substrate with earthworms. It is actually a combination of the washings of the earthworms’ body surface along with the leachate of the vermicomposting substrate.

Fresh coconut leaf vermiwash is alkaline and contains contains major and minor nutrients, growth hormones, humic acid and plant beneficial bacteria. Coconut leaf vermiwash acts as a plant growth stimulator. Application of appropriately diluted coconut leaf vermiwash has shown to increase germination and seedling vigour index of cow pea and paddy seeds in laboratory bioassays. Field trials with cowpea, maize and bhendi in ICAR-CPCRI farm showed its capacity to increase biomass and yield of the crops accompanied by enhanced soil microbial activities.

Adoption of this technology by farmers already carrying out vermicompost production involves very less investment. The vermiwash produced in addition to the vermicompost can be used for improving the yield of crops that give quick returns like vegetables, flowers and also export oriented crops like pepper, nutmeg, clove and vanilla.

Vermicompost and liquid vermiwash produced from other crop residues have also been found to be effective as an organic source of fertilizer comparable with inorganic source of fertilizer and biological disease prevention in a number of vegetable crops.

Coconut leaf Vermiwash production unit

Coconut leaf Vermiwash

Urea-free Coir pith Composting technology

Coir pith is a lignocellulosic waste biomass which accumulates around coir processing factories as a waste material. Though coir pith has a number of beneficial properties, its direct utilization as manure is not advisable as it contains large amounts of lignin and phytotoxic polyphenols.

A simple technology has been developed at ICAR-CPCRI for conversion of coir pith having a C:N ratio of 100:1 to acceptable manure that does not involve addition of urea. The raw coir pith with a C:N ratio of 100% is converted to an acceptable manure with a C:N ratio of 21 to 22 within a period of 45-60 days. The quality of coir-pith compost was found suitable for plant growth. The coir-pith compost can thus form an important recycled soil input for crop production.

For composting 900 kg of coir pith, 100 kg of poultry manure, 5 kg urea and 5 kg of lime are required. The technique involves spreading of coir pith in shaded place, with good quality poultry manure, lime and rock phosphate and mixing them properly. The heap should be kept moist by watering regularly and kept it covered. Once in 15 days, the whole heap must be turned. After 45-60 days, the coir pith will become dark brown to black colour indicating the completion of composting process. The final product is shade dried and packed.

The coir-pith compost produced by ICAR-CPCRI technology is dark coloured with pH in the range of 6.1 to 6.9 and having up to 500% water holding capacity. The N, P and K content ranges between 1.3 to 1.4, 0.9 to 1.2 and 1.3 to 1.6 %, respectively, and is a good source of micronutrients as well.

Coir pith has property of high porosity and high water holding capacity that makes it a unique input as soil amendment. The addition of coir pith compost improves the physical properties and water holding capacity of soils. In addition to these important physical properties, it contains high concentration of potash which makes it more useful. It helps in better root formation and enhances crop growth and is an ideal medium for raising seedlings.

The coir-pith compost produced using the technology developed at ICAR-CPCRI has been released by the trade name ‘Kalpa Soil Care’

Kalpa Soil Care

Irrigation management in cropping systems

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Crops are grown under a range of water management regimes, from simple soil tillage aimed at increasing the infiltration of rainfall, to sophisticated irrigation technologies and management. Of the estimated 1.4 billion ha of crop land worldwide, around 80 percent is rainfed and accounts for about 60 percent of global agricultural output[1]. Under rainfed conditions, water management attempts to control the amount of water available to a crop through the opportunistic deviation of the rainwater pathway towards enhanced moisture storage in the root zone. However, the timing of the water application is still dictated by rainfall patterns, not by the farmer. Some 20 percent of the world's cropped area is irrigated, and produces around 40 percent of total agricultural output[1]. Higher cropping intensities and higher average yields account for this level of productivity. By controlling both the amount and timing of water applied to crops, irrigation facilitates the concentration of inputs to boost land productivity.

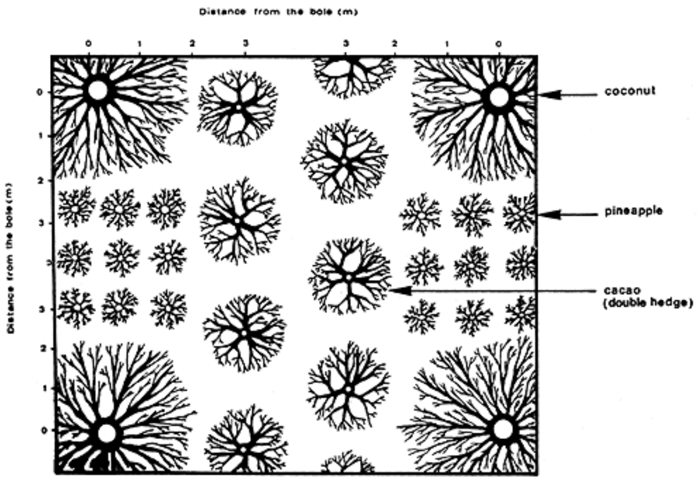
Coconut (*Cocos nucifera* L.) is the major small holder's plantation crop cultivated predominantly in the humid tropics and tropical belts of the country extending throughout the peninsular India comprising of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, parts of Maharashtra, and the north eastern region. They are cultivated in wide range of soils *viz*., sandy, sandy loam, laterite etc. The major socio-economic features in which these crops are cultivated include predominance of small and marginal holdings, medium to resource poor farm environment and less marketed surplus etc. Increasing production by proper and efficient utilization of water and nutrients and harnessing the synergistic interactions among them as the potential yields are the complex functions of both individually as well as interactively would augment the increased productivity of coconut.

One of the critical resources in coconut production is the availability of water. Though the coconut growing regions in the coastal belt are endowed with high rainfall, the rainy period is confined to few months during the monsoon season. The palm experiences moisture stress and drought conditions for varying periods extending up to 6-7 months in a year. In the coconut growing region other than the coastal belt coconut has to be grown throughout the year by supplemental irrigation. The adverse effect of moisture stress on the productivity of coconut has been well established at ICAR-Central Plantation Crops Research Institute (CPCRI), Kasaragod and well documented (Kasturi Bai *et al*., 2009). Utilization of the available water in most effective manner by optimizing irrigation schedules and by adopting soil moisture conservation practices and water harvesting techniques assume particular significance in coconut cultivation. Unfavorable soil and climatic conditions creates moisture stress from December to May and which necessitates coconut palms to be irrigated.

Irrigation methods for coconut

Irrigation methods commonly adopted in coconut gardens are flooding, basin, sprinkler or perfo-spray and drip irrigation. Out of this drip irrigation is most popular for coconut as monocrop and sprinkler irrigation (perfo irrigation) for coconut based cropping system (Dhanapal *et al.*, 1999).

In coconut based cropping system, water lost from one crop area may be used by another crop in the system. Hence system water use efficiency may be more with flood or basin irrigation. Representation of root system in a coconut based cropping system is given below (Nelliat et.al,1974)



In basin irrigation, water is applied in the basins of 1.8 to 2.0 m radius around the palm and there is partial wetting of root zones. Irrigation channels are provided in the centre of the two rows and each basin is connected with this channel. In this method also there is loss due to deep percolation and surface evaporation. Application of water in the basin through use of hose pipe is being advocated to reduce water loss in transit.

Sprinkler or Perfo irrigation

Systematic studies based on the climatic approach on irrigation requirement of West Coast Tall (WCT) coconut palms were conducted at CPCRI, Kasaragod during 1976-1985, in red sandy loam soil. The response to three depths of irrigation water (IW) *viz*., 20, 40 and 60 mm at three frequencies based on IW/CPE ratios of 1.00, 0.75 and 0.50 were studied. Palms irrigated with 20 mm of water at IW/CPE ratio of 1.00 produced the highest cumulative yield of 91.8 nuts palm^{-1} followed by the same depth of irrigation at 0.75 IW/CPE ratio (87.2 nuts palm^{-1}). The mean yield of the palms under the above treatment *viz*. IW/CPE ratio of 1.00 and 0.75 with 20 mm IW were 123 and 121 nuts palm^{-1} year^{-1} respectively (CPCRI, 1988).

Drip irrigation

The concept of surface trickle, often called drip irrigation, has spread from Israel to Australia, North America and South Africa by late 1960 and eventually throughout the world. It has the special features such as, application rate is low, water is applied over a long period to meet the water requirement, avoid wastage and to suit the infiltration rate the water is applied at frequent intervals and water is applied near or into the plants root zone. In cropping system mode, water requirement for trickle irrigation for each crop needs to be worked out separately.

Water requirement of young coconut palms

Climate is the major determinant of the water needed for optimum growth and yield of coconut palms. Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm/day or mm/period. The evaporation (Eo) together with the crop coefficient (Kc) give the water requirement of crop. Since the growth and reproductive stages occur simultaneously after the juvenile period, coconut palm requires readily available moisture throughout its life cycle.

The total water requirement of one year old coconut seedlings was 1591 and 1533 mm per year when irrigation was given at 80 to 100 per cent and 60 to 100 per cent respectively of available soil moisture (Shanthamalliah *et al.*, 1978). It was also reported that coir dust mulching with 15 cm thickness reduced water demand by 40 to 55 per cent. In water scarcity areas burying of pots with 20 1 capacity up to the neck at a distance of 75 cm from the seedling on either side and filling them periodically with water is a common practice to supply sufficient moisture for establishment. The water requirement of young palms in the initial years (up to three years) is very low as the number and size of leaves are small.

Nelliat (1968) reported that irrigation with 45 litres of water once in 4 days combined with application of 0.15 m^3 of red earth in planting pits prior to planting in littoral sandy soil resulted in quick and vigorous growth of young palms. Similar results were also reported from coconut research station, Nileshwar, where 40 liters of water twice a week resulted in vigorous growth of seedlings. Pitcher irrigation in areas of water scarcity by burying the earthen pots of 20 liter capacity at a distance 75 cm from the shoot on either side of the seedling and filling the pots periodically with water, supplies sufficient moisture for establishment and vigorous growth of seedling. The total water requirement was 1591 and 1533 mm per year for maintaining 80 to 100 per cent of available soil moisture and 60-100 per cent of available soil moisture respectively.

Joshi *et al.* (1988) recorded maximum ET of 6.6 mm per day when irrigation was scheduled with 20 mm of water at IW/CPE ratio of 1.00 during March. The ET rates were reduced to 4.0 and 2.3 mm per day when the IW/CPE ratios were 0.75 and 0.50, respectively. Vasu and Wahid (1990) using tritiated water have estimated transpiration of adult coconut palm to be 65 L per day. Mohandas *et al.* (1989) at Coimbatore (Tamil Nadu) measured the transpiration rate of coconut leaves to be 7.5 ^g/cm^2/sec and estimated the total transpiration as 90 1 per day. Varadan *et al.* (1990) have estimated the irrigation depth and interval for coconut based on soil, crop and climatic approach for the various districts of Kerala. From the above review, it is clear that there is much variation with regard to consumptive use of coconut palm and the variations are mostly due to the soil, climate and method adopted for quantification.

Water requirement of adult palms

In coconut, initiation and differentiation of vegetative and reproductive primordia and enlargement of cells are very sensitive to moisture stress. The palm is mostly grown under rain fed condition by the vast majority of coconut growers particularly in the major coconut growing State of Kerala. Excess moisture during the monsoon period which varies from four to six months and moisture stress during summer is a common phenomenon in the west coast of India. The values changed to 2.4 and 2.1 mm day^{-1} respectively when calculated for the first and second week after the rains. Saseendran and Jayakumar (1988) computed the mean yearly consumptive use of coconut to be 1,126 mm (37 1 $palm^{-1}$ day^{-1} for a basin area of 12 m^2). The yearly irrigation requirement was estimated to be 4,656 l $palm^{-1}$ spread over the non-monsoon months of December to May. The mean annual water requirement of coconut plantations in Kerala was 1126 mm (37 litres/palm daily for a basin area of 12 m^2), and the mean annual irrigation requirement was 338 mm (4656 litres/palm for a basin area of 12 m^2), spread over the non-monsoon months of January-May and November and December.

Effect of drip irrigation on nut yield

Significant response in nut yield has been reported due to drip irrigation in different soil types when compared to the yield in rainfed control palms. A field experiment on drip irrigation for West Coast Tall (WCT) coconut was conducted in laterite soil at CPCRI, Kasaragod to study the drip irrigation requirement and its influence on growth and yield. The experimental results revealed that annual leaf production and leaf nutrient status (N and K) of coconut palm was significantly higher in the irrigated treatments compared to the rainfed control. The female flower production and nut yield with 66 per cent of Eo was on par with 100 per cent of Eo through drip and 100 per cent of Eo through basin irrigation. Drip irrigation equal to 66 per cent of open pan evaporation (Eo) proved to be economically efficient method of irrigation with water saving of 34 per cent compared to 100 per cent of Eo through basin and drip methods. The nut characters like nut weight, copra thickness, and copra content were superior under irrigated treatments compared to rainfed control (Dhanapal *et al*., 2004a and b).

In the experiment with high yielding hybrid, COD x WCT, under laterite soil, pooled data on nut yield for six years (1993-99) showed no significant difference among levels of drip irrigation at 66 and 100% of Eo and between the drip and basin irrigation. Drip irrigation at 33% of Eo through drip irrigation failed to produce, significant yield increase over rainfed control. The highest nut yield (119.7 nuts palm^{-1} year^{-1}) was observed in the drip-irrigated treatment at 100 per cent of Eo and was on par with the treatment drip irrigation with 66 per cent of Eo (113.6 nuts palm^{-1} year^{-1}), and the basin irrigation (116 nuts palm^{-1} year^{-1}) (Dhanapal *et al*., 2003).

A field experiment was conducted at Central Plantation Crops Research Institute, Kasaragod, India for six years (1993-1999) to study the impact of drip irrigation levels and mulching on coconut in litoral sandy soil. The treatments consisted of three levels of drip irrigation (66,100, and 133% of open pan evaporation (E_0)) along with basin irrigation (100% of E_0) and rainfed control as main plot treatments and mulching with coconut leaves and no mulching as sub plot treatments. The experimental results revealed that annual leaf production and leaf nutrient status of coconut was better in the irrigated treatments compared to the rainfed control. The drip irrigation at 66 per cent of E_0 (27 litres of water per palm per day during December-January months and 32 litres of water per palm per day during February-May months) resulted in water saving and the nut yield was on par with 100 per cent of E_0 through basin irrigation and differed significantly compared to rainfed control. The nut characters like nut weight, husk weight, copra thickness, copra content and copra yield was superior under irrigated treatments compared to rainfed control. The copra yield was 499 kg per ha under rainfed condition, where as it was 2087 to 2202 kg per ha under irrigated treatments. Irrigation along with mulching with coconut leaves resulted in significantly higher nut yields (Dhanapal *et al*., 2002).

In the same experiment, the available soil moisture was higher by 22.2 to 28.8 per cent in the drip irrigated basins under mulch compared to drip without mulch (Maheswarappa *et al*., 1998). In basin irrigation also, on fourth day after irrigation, the available soil moisture stored in the mulch treatment was 36.8 to 37.6 mm and it was 18.2 to 19.9 mm in the absence of mulch indicating higher level of moisture depletion. Similarly, there was reduction in the soil temperature under irrigated, mulched plots by 1.6 to1.7^{o} C compared to un mulched rainfed plots at 15 cm depth. Drip irrigation along with mulching will be a useful practice with regard to both soil moisture conservation and soil temperature regulation in case of littoral sandy soil. Pooled data on nut yield for four years showed that there was no difference among drip irrigation treatments in littoral sandy soil and between drip and basin irrigation. Nut yield under all irrigated treatments were on a par with each other but were significantly superior to that of rainfed control (26.8 nuts /palm/year).

Coconut yield under drip irrigation with 30 and 45 litres day palm was on par with basin irrigation at 600 litre per palm per week . The main reasons for 34 per cent water saving through drip treatment were the reduction in the quantity of applied water and avoidance of loss due to deep percolation. Though more water was applied under 100 and 133 per cent Eo under drip and basin irrigation, it did not contribute towards higher yield, probably because the excess water might have moved beyond the root zone and was not used by the palms. Venkitaswamy *et al*., (1997) reported that nut yield under drip irrigation at 100 per cent of Eo was on par with basin irrigation at IW/CPE ratio of 1.0.

A trial conducted to evaluate the economic viability of trickle irrigation on a full bearing coconut plantation in the south Saurashtra region of Gujarat, India, indicated that it can save 45-50% water over surface irrigation without any significant reduction in yield (Kapadiyal *et al*., 1998). With the water thus saved one extra hectare can be brought under irrigation thereby increasing the net income of the farmers.

The experiment on drip irrigation was conducted at Agricultural Research Station, Arsikere, Karnataka during 2000-05 in a 25 year-old coconut garden of local cultivar-Tiptur Tall. The quantity of water given through drip system was based on the 10 years average of mean monthly evaporation. Irrigation either through drip or basin system significantly increased the nut yield of coconut over rainfed control. Drip irrigation at 100 per cent Eo recorded significantly higher nut yield compared to drip irrigation @ 33 per cent Eo and 66 per cent Eo and was on par with basin irrigation at IW/CPE equal to 1.0 at 3 cm depth. The rainfed control recorded significantly lower nut yield compared to treatments of providing drip or basin irrigation. The increase in nut yield in irrigation treatments over rainfed control was due to more number of functional leaves, production of more number of flowering bunches and female flowers. The leaf nutrient status was also increased with irrigation. The net returns and B:C ratio were highest with drip irrigation at 100 per cent Eo followed by basin irrigation and drip irrigation at 66 per cent Eo. Hence, drip irrigation at 100 per cent Eo is found suitable for coconut in the *maidan* tract of Karnataka. The water to be applied during summer months (February-May) is 65-75 litres/palm/day while for winter and rainy months (June-January) is 40-50 litres/palm/day (Basavaraju and Hanumanthappa, 2009).

A field experiment on effect of drip irrigation on yield of 35 years old West Coast Tall (WCT) coconut was conducted in sandy soil of Konkan region of Maharastra at Regional Coconut Research Station, Bhatye under All India Coordinated Research Project on Palms, the result indicated that the basin irrigation (T5) resulted in highest yield over T1 control (no irrigation), T3 (66% Eo) and T2 (33% Eo) and was at par with drip irrigation T4 (100 Eo). Drip irrigation at 100 % Eo (T4) was significantly superior over T1 (no irrigation) and at par with T3 and T2. The cost benefit ratio was highest in T4 (1.50) followed by T3 (1.42). The water saving was 34% in T3 over T4 and 43% in T3 over T5. Considering the yield per hectare, cost benefit ratio and saving of water the drip irrigation with 30 liters of water/palm/day during October to January and 40 liters during February to May with four drippers placed at a distance of 1 m. away from the bole is recommended for the sandy soil in Konkan region (Nagwekar *et al*., 2006).

Response of coconut roots to drip irrigation

Study conducted by Dhanapal *et al*. (2000) have revealed that, number of main roots from one fourth of the basin area were higher under irrigated palms compared to rainfed palms. The response for irrigation of the fine roots was more compared to the main roots. Irrespective of the methods of irrigation the dry weight of roots were more in the irrigated palms compared to the rainfed palms under littoral sandy soil. Since the main as well as fine roots were more in the limited area of the wetted zone under drip irrigation, the performance of drip irrigated palms was on par with basin irrigated palms.

Fertigation

Drip fertigation increases the fertilizer use efficiency, saving in fertilizer costs, reduced labour requirement, supplying nutrients according to crop demand during varying physiological stages. Soluble fertilizers *viz*., urea and potassium chloride can be combined and supplied through drip irrigation.

Fertigation is a key to higher yields and healthier crops

- The most effective method for adding chemicals and fertilizers to crops via the existing irrigation system
- Simple operation, adjustments and maintenance
- Liquid chemical is applied directly with the water system
- Liquid chemical is applied only when needed and in the proper quantities
- Most effective and least expensive way of providing nutrients to growing field crops

At Central Plantation Crops Research Institute, Kasargod, fertilizers like urea, diammonium phosphate, and muriate of potash were tried as source of NPK nutrients through fertigation. To use Diammonium phosphate (DAP) in fertigation, water should be added to DAP and should be kept over night so that DAP gets dissolved in water. This solution after filtering can be directly used in fertigation tanks for supply of N and P nutrients. These fertilizers in the form of solution can be added in the fertilizer tank meant for that purpose or pumped in to the system through venturi unit. Conventional method of fertilizer application and providing irrigation to coconut is labour extensive. Thus fertigation where fertilizer is applied through drip irrigation saves labour and money other than uniformity in application of fertilizer is possible. Fertilizer to the tune of 50% and irrigation water to the tune of 40% can be saved. Improvement in coconut yield was experienced as soil is maintained at field capacity and also due to increased fertilizer use efficiency. The experiment results indicated that fertilizer application at the rate of 50% of the recommended dose of fertilizer through drip irrigation produced an yield equivalent to 100% of the recommended dose of fertilizer applied both by conventional as well as through drip irrigation.

An investigation was conducted to study the response of drip fertigation in West Coast Tall variety of coconut for growth, nutrition, physiological parameters and yield at Central Plantation Crops Research Institute, Kasaragod during 1996-2008. The application of fertilizers either through drip fertigation or soil application resulted in significantly higher trunk height and girth at base than control (no fertilizer). However, no significant difference was observed among different dose of fertigation and soil application treatments. Among the fertigation levels, coconut yield was significantly higher in 100 per cent NPK fertigation (131nuts/palm/year) which was on par with 75 and 50 per cent NPK applied through drip irrigation and significantly differed from 100 per cent NPK through soil application, 25 per cent NPK through fertigation and control. The study indicated that adoption of fertigation increases the productivity with 50 per cent saving of chemical fertilizers which ensure the higher efficiency of nutrients in crop production (Subramanian *et al*., 2012).

An experiment to study the effect of fertigation on the productivity of coconut was laid out at Horticulture Research Station, Arsikere, Karnataka during 2007-08 to 2011-12. The study indicated the possibility of saving 25 per cent of the recommended fertilizers by adopting fertigation which ensures higher productivity in coconut (Basavaraju *et al* ., 2014).

A field experiment to study the effect of fertigation on the productivity of coconut was carried out at the Horticultural Research Station, Kahikuchi of Assam Agricultural University during 2009-10 to 2012-13. Application of 25, 50, 75 and 100 per cent of recommended NPK through drip irrigation system was compared with the soil application of recommended NPK as well as control with no fertilizer application. The net returns in 75 per cent NPK through drip irrigation were also on par with the application of 100 per cent NPK through drip irrigation, but application of 75 per cent NPK through drip irrigation recorded significantly the highest benefit-cost ratio compared to all other treatments. The study indicated the possibility of saving 25 per cent of the recommended fertilizers by adopting fertigation which ensures higher productivity in coconut (Nath *et al.,* 2016).

An experiment was carried out at experimental farm, Regional Coconut Research Station, Bhatye, Ratnagiri during the year 2006 to 2013, with four replications and six treatments viz. T control (No fertilizer), T 25% of recommended dose of NPK through drip, T – 50% of recommended dose of NPK through drip, T – 75 % of recommended dose of NPK through drip, T – 100% of recommended dose of NPK through drip, T – 100% of recommended dose as soil application. Economic analysis of fertilizer application revealed that treatment T (100% RDF through drip system) recorded highest net returns (Rs. 108090 ha). Also it was observed that there was increase in NPK content of soil due to fertigation treatment (Khandekar *et al.*, 2016).

Based on the studies taken up on fertigation in coconut and oil palm at different centres of AICRP on Palms from 2007-08 to 2012-13, the following recommendations have been made for different regions of the country (Maheswarappa and Rajkumar, 2014);

- **Aliyarnagar,Veppankulam Mandouri and Kasaragod Centres:** The nut and copra yield per palm per year in fertigation of 50% RDF was on par with fertigation of 75% RDF and soil application of 100 per cent RDF.
- **Ambajipeta, Arsikere Centre:** Application of 75% RDF through fertigation recorded significantly higher nut and copra yield per palm per year compared to soil application of 100% RDF and on par 100% RDF through fertigation.

Seawater irrigation for coastal sandy soil and other porous soil of the coastal belt

This is best suited for the soils of coastal belt. There is a condition for seawater irrigation *i.e*., the area should experience heavy rainfall and the soil of that area should highly porous. The use of quality water for irrigation is of paramount importance for agricultural crop production. However, crops differ in their tolerance to poor quality irrigation water. The perennial crops have advantages over the annuals and biennials in tolerance capacity *i.e*., their life cycle extends over a long period and thus we cannot critically pin point, which stage is affected more and even if affected in one season, it can recover in the ensuing wet season. Thus the coconut, which is predominately grown along the coasts of Kerala, Andhra Pradesh, West Bengal, Odisha etc., can be irrigated with sea water for its sustainable productivity.

The availability of fresh water in the Islands and coastal belt for irrigation is very limited but nature has blessed with two favourable situations i.e., abundance rainfall and porous soils which enables seawater irrigation in the Islands like Andaman, Lakshadeep in India and other countries like Maldives and Sri Lanka. The response for irrigation in coastal sandy soils is tremendous. Coconut can tolerate a pH of 8.5. Since the coasts are fed with high rainfall the accumulated salt due to, seawater irrigation during summer months can be easily washed away from the root zone during the wet season.

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Enhancing income through floriculture in coconut gardens

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Coconut gardens offer greater scope for intercropping which is not possible in many of the plantation crops. This is mainly due to the wider spacing of 7.5m, unbranched stem and compact terminal crown of leaves. Coconut palms use only 25% of total land area. The unutilized soil resources and under storey sunlight in plantations can be used effectively by growing compatible inter crops which do not affect the growth and yield of palms. With changing life styles and increased urban affluence, floriculture has assumed a definite commercial status in recent times and during the past 2-3 decades particularly. Appreciation of the potential of commercial floriculture has resulted in the blossoming of this field into a viable agri-business option.

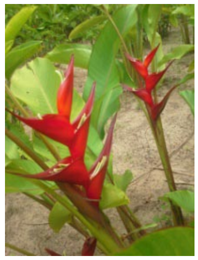
In general flower crops come up well in full sunlight. Lack of open spaces is the limiting factor for commercial floriculture. Cut flowers such as orchids, anthuriums, selected commercial varieties of Heliconias etc performs better under shaded condition. Growing flower crops of higher market demand is a promising venture in coconut plantations. Only limited capital is needed to start up intercropping of compatible flower crops in coconut gardens, and many can view it as a second income or post retirement occupation. It also has immense potential for attracting women and youth in agriculture. The domestic demand for flowers is growing annually by 15-20 per cent in major cities. World trade on floriculture produces like cut flowers, ornamental plants, flowering plants, flower seeds and plantlets are gaining tremendous momentum.

Heliconias

Heliconias are newly identified cut flowers in our country and becoming popular. Among the tropical flowers, Heliconia is outstanding for its diversity in form, colour, size and particularly, its vase life. Heliconia flowers are actually highly modified leaves called bracts, which may be erect, pendulous or spiraling in the shapes of bird's beaks, lobster claws or fan shaped and with colors of reds, pinks, gold, oranges and splashes of a mixture of colours. The genus is made up of about 100 species along with a large number of hybrids and cultivars. The requirement of light for growth and flowering varies with species to species. Heliconia needs to be replanted after 3-4 years.

Commerical Heliconia varieties suitable for coocnut gardens

Heliconia stricta ‘Iris’, *H.bihai* X *H.caribaea* ‘Kawauchi’, *Heliconia stricta* Sunrise and *H. orthotropica* ‘She’, were suitable as intercrop in coconut plantations.


Cv.She Cv.Sunrise Cv.Kawauchi

A combination of varieties She (Fig.1) and Sunrise (Fig.2) can be planted in 1:1 ratio for year round production of inflorescences.

Fig.1

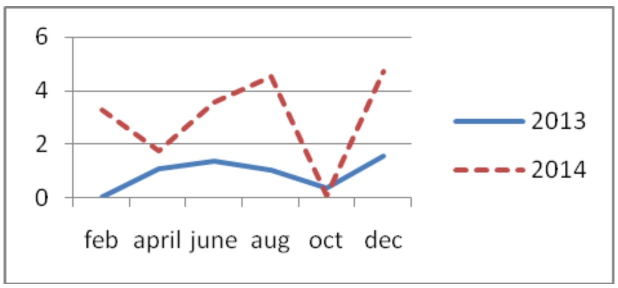
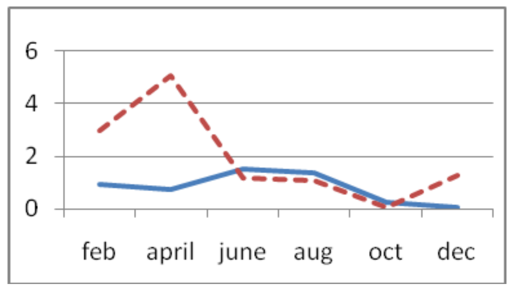


Fig.2



X-axis : No. of inflorescence produced/month ; Y-axis : Months on a year

In general plantations of palms aged 8-25 years are not suitable for intercropping due to over shading. *Heliconia stircta* cv Iris performs best in more than fifty percent shade. The growth and performance of *Heliconia stricta* 'Iris' was found to be positively related to shade intensity. The plants grown under 65-70 % shade produced higher number of inflorescences (100 nos.yr^{-1}clump^{-1}) with best quality from second year of planting. The inflorescences produced have more than one meter length, 6-8 number of bracts and 9cm stem girth with higher carotenoid (0.13mg.g^{-1}) and xanthophyll (0.99 mg.g^{-1}) contents. A single inflorescence of *Heliconia stricta* 'Iris' can fetch Rs. 20 to Rs.250 in the national market. Large flowers of more than one meter length can fetch $2 to $18 each in International markets.


Planting material

Seven months old rhizomes with more than nine centimeter collar girth can be used as planting material. After removing the leaves, rhizomes cut back at one meter height from the basal end is used as planting material.

Planting

Heliconia rhizomes are planted in pits of size 30cmx 30cmx30cm.Planting can be done except during winter and heavy monsoon seasons. For commercial cultivation, at least 250 plants are to be planted which requires 25cents of coconut plantation. The rhizomes are planted at 1.5 m spacing leaving an area of 2m around the coconut basins. The pits are refilled with topsoil mixed with dried cow dung (1kg/pit) and bone meal (250g/pit).Mulching with dried leaves or coir pith is done after planting. Rhizomes start sprouting at forty five days after planting. Thinning of slender stems (less than 7cm diameter) should be carried out monthly for promoting more number of quality inflorescence.

Manuring

Heliconia can be grown either purely organic or in an integrated way using organic manures and chemical fertilizers. The manures and fertilizers are applied at quarterly intervals beginning from three months after planting. For organically grown Heliconias, 200g vermicompost and 100g neemcake are applied per plant at three months interval. For integrated method of cultivation, half the dose of vermicompost and neemcake (100g and 50 g per plant) along with 13:5:13 NPK (5g/plant) can be given at three months interval .In both the conditions, drenching diluted cow dung slurry in the ratio 1:10 at six monthly interval enhances the production of quality inflorescence.

Harvesting

The harvesting is usually done before 9am in the morning or after 4pm by cutting the rhizome along with the inflorescence at ground level. After cutting, the outer leaves are stripped off and the top most leaf blades are cut leaving the petiole. The inflorescences have 10-12 days of vase life and are used in stage decorations, bouquet making, long arrangements etc.

Inflorescences of around one meter length and nine centimeter stem girth with 2 or more open bracts are selected for sale. Smaller inflorescences can be used for value addition such as bouquets and table top arrangements. In order to remove the field heat, the cut end of the inflorescence stem is dipped in tap water for about an hour. These are then washed in water for removing soil and dust .The excess water is wiped off and inflorescences are graded based on their length. Inflorescence with fewer flowers inside the bracts are ideal for marketing as it will reduce time and cost of cleaning and minimize occurrence of insects, odours from water accumulation and organic matter deterioration.

Grading of Heliconia inflorescences

Grades	Length of inflorescence (cm)	Stem girth (cm)	Spike width (cm)
Grade I	>100	>9	>25
Grade II	100-75	9-7	20-25
Grade III	<75	<7	<20

Direct marketing

By adopting direct marketing farmer will get maximum benefit. It can either be sent directly to star hotels in major cities of India or can be used for value additions such as flower arrangements or bouquets. Bouquet making and flower arrangements are profitable value additions which can be adopted by women self help groups located in major cities.

Economics of cultivation

The economics of intercropping *Heliconia stricta* cv. Iris for three years in one hectare of coconut plantations is given below:

Year	Input cost (Rs.)	Returns (Rs.)		Net returns (Rs.)	Benefit cost ratio
		Inflorescence @ Rs20/-	Rhizomes @Rs.60/-		
I yr	5,87,000	96000	-	-4,91,000	
II yr	10,20,000	21,60,000	9,00,000	30,60,000	3:1
III yr	16,00,000	27,00,000	21,60,000	48,00,000	3:1

The initial cost of cultivation is very high due to the cost of planting material which may require financial support from banks etc. The cultivation of Heliconias open up scope for employment generation and youth empowerment through export, value addition such as bouquet making, flower arrangement, stage decoration etc. Additional labour employment of 1000 man days/ha in the first year,1800-2000/ha in second year and 2500 man days/ha in third year is expected.

Marigold- Gomphrena sequential intercropping

Introduction of annual ornamentals in the interspaces of coconut garden enhances the aesthetics and provides additional farm income in a short period of time. Marigold (*Tagetus erecta*) of Compositae family and *Gomphrena globosa* (Globe amaranth) of Amaranthacea family are two potential commercial flower crops that are gaining global popularity as specialty loose flowers. These can be used both as fresh and dry flowers for making various floral decorations. Marigold flower is also an important source of carotenoids with application in the food industry and dying fabrics.

Marigold

Globe maranth

Marigold and Globe amaranth can be grown in coconut gardens with more than 75% light penetration leaving a distance of 2m from the base of coconut palms. Young plantations of 1-2 years or mature gardens above 25 years are more suitable for this sequential cropping system.

Planting material and Sowing

Seeds either collected from mature flowers or authorised dealers with good viability and germination percentage are to be used for sowing. The seeds wil germintae in five to six days time.

The seeds can be sown in shallow pots filled with potting mixture prepared using soil,sand and compost or dried leaf powder in the ratio 2:1:1. The potting mixture is then levelled and line sowing is done at a shallow depth. The sown seeds are covered with newspaper for maintaing humidity.The news paper is removed as soon as the seeds start germinating. Then the seedlings are gradually trasferred to full sunlight in three to four days.

Seeds can also be sown in raised beds of 60cm height, 1.5m width and 2m length. The top soil is mixed with vermicompost @ 1kg. m^{-2}. The seed beds are then covered with dried coconut fronds till the seeds start germinating.

Planting

The seedlings are transplanted when they produce three to four functional leaves. Marigold seedlings are tansplanted at 45cm x 45 cm spacing and Globe amaranth seedlings at 60 cm x 60 cm spacing.

Marigold can be planted in trenches of 15cm deep taken at 45 cm apart. This method of planting helps in increased soil moisture retention and reduced lodging. Since Globe amaranth is grown during rainy season, they are to be transplanted in raised beds of 3m x 4m x 15cm (l x wx h) for avoiding water stagnation and rotting of seedlings.

Manuring

In this sequential cropping system, Marigold alone is supplied with adequate quantity of organic and inorganic nutrients and Globe amaranth is grown as a catch crop utilizing the residual soil nutrients till 60 days after transplanting (DAT).

In coconut plantations, considering the light requirement, only 30% of land area (75 cents) is suitable for this sequential cropping system.

The manure requirement of the cropping system is as follows:

a) Marigold

Marigold seedlings are planted in trenches after basal application of vermicompost @ 900kg/ha of coconut garden. After fifteen days of transplanting, plants are supplied with chemical fertilizer mixture (16.8: 18:18 kg NPK/ha of coconut garden) @ 5g/plant. This mixture can be prepared by mixing urea, Rock phosphate/Rajphos and MOP in the ratio 6:19:5. This is followed by spraying and drenching with vermicompost extract (VCE) at 30 days and 45 days after transplanting. Spraying and drenching of VCE (1:10) helps in production of bigger flowers with more carotenoid content.

VCE (1:10) preparation

Vermicompost equivalent to 8.4 Nha^{-1} (450 kg) is to be taken and mixed with tap water in 1:1(w/v) ratio and kept overnight. The quantity of vermicompost is taken considering the recovery of extract from vermicompost which is estimated as 57 %. VCE may be diluted with water in 1:10 ratio (w/v) and sprayed to plants @1.7 l/m^2 at 30 and 45 DAT.

b) Globe amaranth

The residual soil nutrients after growing Marigold can be effectively utilized for growing Globe amaranth till its vegetative phase (60 DAT). After that an additional dose of 18:18:18 NPK (5g/plant) is supplied at fortnightly intervals till two weeks before the final harvest (150 DAT).

Intercultural operations

After transplanting, the seedlings of Marigold require shade for first two weeks. First weeding is done at two weeks after planting just before application of chemical fertilizers.

Marigold plants are prone to lodging when grown in raised beds. In order to avoid lodging staking is given at 60 DAT. Staking can be done to individual plants .If the plants are planted in a line then line staking can be given by erecting two bamboo sticks on either ends of the line.

For Marigold, regular pinching and disbudding should be done were done up to 45 DAT. Pinching helps in proper branching and increased flowering. This helps in production of bigger flowers. No such cultural operations are necessary for Globe amaranth.

Plant protection

Rotting of plants is the major problem in Marigold. If rotting is noticed the affected plants are uprooted and destroyed along with the rhizosphere soil. The remaining plants are sprayed with any systemic fungcide @3ml.L^{-1}

Attack of grass hopper is another problem in transplanted seedlings. The attack can be prevented by providing a sheild around the seedlings. For this, farmers practice ringing of individual plants (providing a shield around the seedlings) using mango or jackfruit leaves.

Harvesting and marketing

The flowers are harvested during evening hours as the dew drops on the flowers during early morning reduce the keeping quality. Fully opened flowers along with peduncle are harvested for sale. For marigold grading of flowers before marketing ensures better price. Small sized flowers can be marketed for making garlands in local shops and restaurants. The demand of these flowers during festive seasons is very high that the whole produce can easily be marketed among the local vendors at reasonable price.

ADDITIONAL INCOME

Additional benefit from unit intercropped area of coconut garden (30% area) by introducing Marigold-Globe amaranth sequential cropping system is given below:

Commodity	BCR	Quantity/ ha	Unit price (Rs)	Benefit (Rs)
Marigold flowers (kg)	3.4	2800	50	140000
Globe amaranth flowers(kg)	2.6	1750	40	70000
Additional coconuts (nos)		531	15	7965
Total additional income				217965

Intercropping flower crops in coconut gardens results in proper irrigation of the interspaces resulting in enhanced water and nutrient use efficiency of palms. It will result in improved yield of coconut palms which is mainly due to reduced button shedding. It also fetches additional income through sale of flowers and planting materials from a short period of time. So floriculture in coconut gardens can be adopted as a promising venture for doubling farmers income.

Scope and approaches for precision farming in CBFS

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Precision agriculture is about managing the spatial and temporal variability of the factors associated with agriculture through scientific interventions in order to improve the productivity, profitability and environmental quality. Precision farming aims to apply the right input, at right time, at right place and at right quantity to attain potential productivity while minimizing environmental damage and increasing the economic profitability. Precision farming at field level is very successful when there is manageable variability existing within the field. Therefore, the basic step in precision farming is assessing the variability in spatial and temporal domain within the field incase of a field level approach and within a region in a larger scale precision farming approach. Once, the existing manageable variabilities are identified and delineated, tailor made management practices can be formulated and applied to improve the productivity. Precision farming components like Global positioning system (GPS), sensors, Geographical information systems (GIS), Decision support systems, computers and variable rate applicators are employed in the process of precision farming for the collection and analysis of variability and imposing management practices.

Assessing spatial and temporal variability

Yield variability

Yield variability in the spatial and temporal domain within the field or region is the first step in precision farming to understand the difference in the yield. The yield variation may be due to any factor. In case of coconut based farming system yield of different component crops needs to be recorded spatially and temporally. Spatial data collection on yield can be done using Differential GPS (DGPS). Based on this data yield map of the field can be prepared using the GIS. In case of the small holdings without any access to the Differential GPS or GIS, field harvest record of the individual palm and intercrops and yield of sub plots for field crops can provide the required information. For achieving this, all the palms and perennial intercrops should be numbered serially for their location identification and recording the yield data. Single year data may be affected by various environmental factors therefore yield data of more number of years will provide the yield information less influenced by climate. More over temporal dynamics of the yield can also be obtained for the analysis.

Soil resource variability

One of the most important variability behind the yield variations is soil properties which influences the key inputs like water and nutrient supply to crop. Soil texture and compactness affects the root growth of the crop. Water holding capacity of the soil is the key property considered for plant water supply and the irrigation scheduling for ensuring optimum water availability to plant. Soil fertility variability which arises out of difference in the natural nutrient supplying power of the different soil types and also the varying nutrient management practices followed and crops grown. Soil fertility variation is highly varying with space and also with time. Hence, warrants periodical assessment to get reliable data for precision farming.

Grid based sampling can be done to develop the soil variability map. Grid size can be fixed based on the variability existing in the field. Representative samples are collected from each grid. At each grid line intersection, a composite sample is collected by pooling the samples collected from adjacent palms or random samples can be collected from the palms in the grid. Similarly, sample is collected for the perennial intercrops separately. For grass component, collect samples from the adjacent points. Geo-location data of the sampling sites using DGPS should be collected simultaneously during the sampling. For coconut palm, leaf samples of coconut are collected from the 14^{th} leaf or the middle leaf of the total number of leaves in the crown. Respective leaf sampling procedures prescribed for the intercrops should be followed for sampling intercrops.

If grid sampling is not feasible, a farm can be divided into different parcels according to the difference in the nature of soil type, topography, management practices followed and crops grown. This can be further divided based on the yield variation if any exists within each unit. Finally, the farm is divided in to different management zones. Each management zone should be homogeneous in its yield limiting factor and a single rate of input can be applied to the entire unit.

Representative soil samples can be collected from each specific unit and analyzed separately to understand the soil fertility status. In CBFS, individual coconut basin sample can be collected for a small farm. If not possible, representative soil samples can be collected for each grid or management zone delineated. For coconut, soil samples are collected from the basin that is one meter away from the bole of the coconut (in the manure circle) and up to one meter depth (at least 60cm depth). Each 30cm depth soil is collected separately. More number of random samples from each grid or from each management zone should be collected and can be pooled to get one composite sample per grid or for each management zone. Soil samples should be collected separately for each inter crop following the soil sampling procedures recommended for the respective crop. For shallow rooted annual crops, soil samples can be collected following the V cut method where V shaped cut is made using a spade to a depth of 15cm. The cut soil is removed then the soil from the sides of the V cut is scraped to collect soil. For deep rooted annual crops this cut can be made for 30cm. If the core samplers are available core samples up to the required depth can be collected. For the perennial intercrops like shrubs or tree crops soil samples should be collected from the entire effective rooting depth vertically. DGPS information on sampling locations should be collected simultaneously in order to develop thematic maps for spatial analysis of variables and management application map.

Remote sensing application in precision farming

Information on soil properties and plant health information like moisture stress, nutrient deficiency and pest and disease occurrence can also be obtained through the sensors. High resolution spectral data can be collected through satellites and also from aerial or ground level data collection. These types of advanced data collection methods can provide timely information and also more number of revisits is possible. Hence, periodical monitoring of the crop health is possible and therefore immediate action on the correction of problem can be made.

Sensors

There are optical, dielectric, electrochemical and mechanical sensors available to collect the information on soil properties. These sensors can provide realtime information of the changes in the soil property also. But the information from these sensors needs calibration with the laboratory data to get more accurate information about the variable.

GPS, GIS and Decision Support Systems in Precision farming

GIS software enables to map the georeferenced data of a variable to be mapped. Apart from the spatial data storage and display, this software is used to further analyse the spatial data to understand the spatial variation and to analyse the relationship between the variables. Thematic maps are prepared for individual nutrients. Nutrient variability maps should be prepared separately for each crop in CBFS system. Various management options can be established and spatial information on what and how much of the input should be applied can be developed as application map.

Thematic maps for nutrient status are prepared with the DGPS data and the analytical results of the soil and leaves using the GIS software. DGPS provides precise location information so that spatial maps of the variables can be prepared and analysed. DGPS helps in revisiting the accurate location for the management. Decision support systems are the expert systems which produce recommendations based on the input data and the models for the evaluation and recommendation of fertilizers and other inputs.

Managing the variability

The optimum nutrient content in soil and leaf and the nutrient recommendation based on soil test value varies with the individual crop, therefore the application maps should also be prepared separately for each crop. This site specific fertilizer recommendation can be applied to the respective crops using a variable rate applicator or manually. In general, in CBFS, fertilizers are applied manually to the individual palm and the individual perennial intercrops, therefore applying variable rates of fertilizers is feasible but it is time consuming and labour intensive. This site specific delivery of the fertilizers is guided by the DGPS and the application maps. Through this approach pH amendments can also be made.

Sustainable CBFS approach

For sustainable CBFS the nutrient input and output of the individual component crop should be worked out. The management should consider achieving balance between input and output. Similarly, farm gate nutrient budgeting will also help in achieving long term sustainable nutrient management and thereby will sustain soil health and crop productivity under CBFS in long term.

Value addition through product diversification in coconut

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Introduction

Coconut palm (*Cocos nucifera* L.), a perennial horticultural crop, is a symbol of national and international integration involving more than 93 producing countries and more than 140 consuming countries. It is eulogised as 'Kalpavriksha'- the '*tree of heaven*' as each and every part of the palm is useful to mankind in one way or other. There are countless uses of this coconut palm. It is bestowed with multiple benefits like health, wealth and shelter to mankind. It is also denoted as "heavenly tree", "tree of abundance" and "nature's supermarket".

Scope of entrepreneurship development in coconut processing sector

Majority of the farmers engaged in coconut cultivation mainly have small and marginal scattered holdings. This hampers the prospects of processing and value addition in coconut. Presently, coconut growers are more exposed to economic risk and uncertainties owing to the high degree of price fluctuations. Further, the mindset of traditional coconut grower is attuned to processing for copra and coconut oil. The coconut-based economy can expect a revival only when the profitability of coconut farming is delinked from the price behaviour of coconut oil. This is possible through efficient utilization of the land under coconut cultivation and post harvest value addition activities.

India has not made tangible progress in product diversification and by-product utilization of coconut except for the traditional activities such as oil milling and coir processing. As a result, coconut oil continues to be the only major coconut product having influence on the farm level price of coconut. The present level of value addition is 8% which needs to be increased to at least 25%. This situation can be transformed only when coconut based both edible and non-edible products gets priority over coconut oil. As compared to the tardy growth recorded by the country in the processing sector, most of the coconut growing countries are making profit from the production and export of diverse coconut products. Philippines, Indonesia and Thailand realizes more than 50% value addition level, export over 40 non-traditional products of which coco chemicals, coconut milk products, coconut water based products, and shell and coir products are important.

Product diversification and value addition play a crucial role in the stabilization of the coconut oil driven market and is essential for reorienting and energizing the coconut industry cost effective and globally competitive. Hence, there exists a huge scope for coconut based agri-business in India. The processing and related activities can mitigate the seasonal price variation and generate income and employment opportunities for over two million people in India.

Entrepreneurship development through coconut value addition

Coconut is mainly consumed as fresh nuts, tender coconuts, coconut oil and copra meal. Around 50 per cent of the world production is consumed in the form of fresh nuts and tender nuts. Close to fifty percent of the nut production is converted into copra and consumed as coconut oil and copra meal. Around 2.52 per cent of the production is consumed as desiccated coconut. In India, annual consumption of tender coconut is about 200 million. The coconut palm also provides a series of by-products such as fiber, charcoal, handicrafts, vinegar, alcohol, sugar, furniture, roofing, fuel, etc. and it has more than 200 diversified local uses. The products and by-products of these crops form vital inputs for many of the industries and support the livelihood of many millions. They contribute a significant amount to the national revenue and country's exports by way of excise and export earnings. They also provide direct and indirect employment to a large number of people in the country. The potential of converting coconut into different emerging value added products such as desiccated coconut powder, virgin coconut oil, coconut chips, coconut milk, preserved tender nut water & coconut inflorescence sap into coconut sugar is realized in view of globalization over the traditional processed products of copra and coconut oil.

Value added food products from coconut can be broadly categorized as,

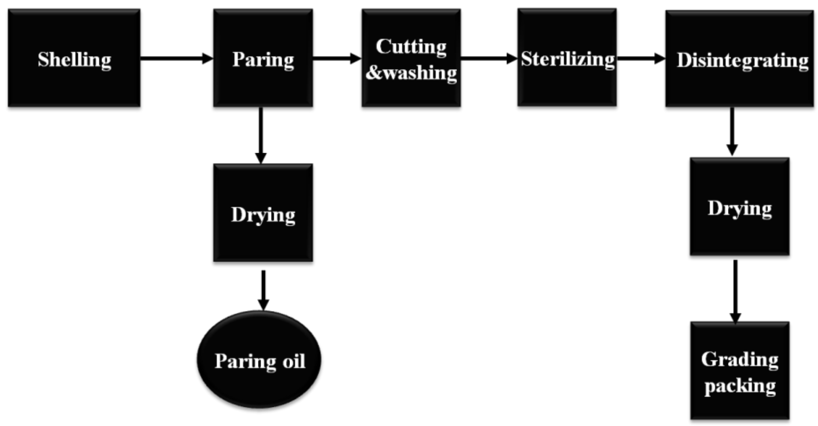
1) Products derived from mature coconut kernel
2) Products derived from mature coconut water
3) Products derived from tender coconut water
4) Products derived from coconut inflorescence sap

1. Products derived from mature coconut kernel

Coconut reaches full maturity in about 12 to 13 months time after the opening of inflorescence. Mature raw coconut are used for culinary uses, religious purposes, making copra and manufacturing convenience products such as desiccated coconut, coconut milk, spray dried coconut milk powder, etc. About 40% of the Indian annual coconut production goes to culinary and religious purpose, 35% for copra production, 17% for tender nut purpose, 2% for seed purpose and only 6% is the share of value addition which comprises of desiccated coconut powder (4%), virgin coconut oil and coconut milk/ cream (1% each).

a. Desiccated coconut

Shredded and dried white kernel or endosperm is marketed as desiccated coconut. It is rich in healthy medium chain fatty acids with no cholesterol and an excellent source of dietary fibre. The steps involved in processing of desiccated coconut involves selection, sorting and husking of coconut, shelling, paring, washing, sterilizing, grinding, drying, sieving, packing, and storage. The main uses of desiccated coconut are for the confectionary industry, as a filling for chocolates and candies; the bakery industry for biscuits, cake and nut filling products; direct usage to decorate cakes, biscuits and ice cream and preparation of various snacks. Over the last few years, import of desiccated coconut across the world grew by 19% in value and 4.1% in quantity, which provides opportunities for new suppliers from developing countries. During the year 2015-16, India exported 4261 MT desiccated coconut worth Rs. 52.60 crores. In comparison with the export figure of previous year, India achieved an increase to the tune of 60%, which indeed is a remarkable achievement. There exists an immense export potential for the desiccated coconut across the world. The flow chart of desiccated powder preparation and techno economic details are described below,



Techno economic details

Machineries required	Coconut dehusker, desheller, testa remover, washing unit, inspection conveyor, blanching unit, pulverizer, fluidized bed dryer, desiccated powder cooler, lump breaker, vibro siever, packaging unit.
Capital Investment	Rs.130 lakhs for processing 15,000 nuts per day
Yield	1 ton from 10,000 coconuts

(Source: Coconut Development Board)

b. Virgin coconut oil (VCO)

It is the oil obtained from fresh, mature kernel by mechanical or natural means, with or without use of heat and absence of chemical refining, bleaching or de odourizing. It is called “virgin” because the oil obtained is pure, raw and pristine. It has a fresh coconut aroma ranging from mild to intense depending on extraction process. It is extracted directly from the fresh coconut meat or from coconut milk. The different methods involved are hot-processing, natural fermentation, centrifugation and direct micro expelling. The choice of the technology to be adopted depends to a great extent on the scale of operation, the degree of mechanization, the amount of investment available and the market demand. It is estimated that, after producing 4200 kg of hot process virgin coconut oil, the no profit no loss point will occur which will correspond to a respective sale volume of Rs. 33.5 lakhs and this respective stage will arrive after 168 days of functioning of the unit. Therefore the VCO making unit will start earning profit from sixth month after installation.

ICAR-CPCRI has developed processing technologies for production of VCO by hot and fermentation methods. In hot process, coconut milk is cooked in specially designed cooker whereas in fermentation process, coconut milk is allowed to ferment in specially designed fermentation tank for specified period to get VCO. The process protocol is given below. The quality characteristics of VCO produced by hot and fermentation processes in comparison with commercial coconut oil is furnished in Table 1.

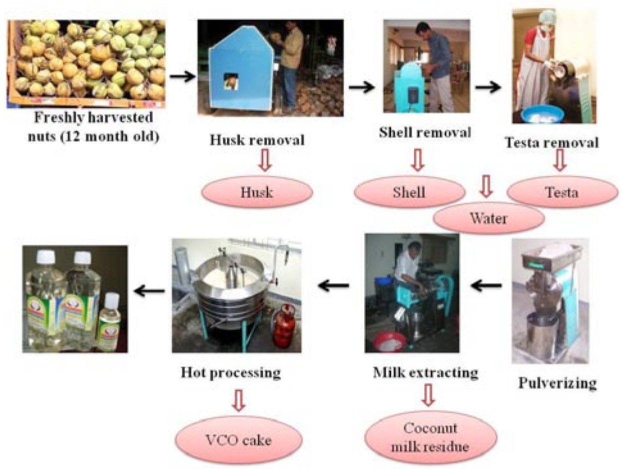


Fig. Flow chart of VCO processing

Table 1. Comparative quality characteristics of VCO produced by hot and fermentation processes with commercial coconut oil

Chemical parameters	**Hot-process VCO**	**Fermented VCO**	**Commercial Coconut Oil**
Tocopherol (µg/g) (Vitamin E)	15-20	20-30	2-6
Polyphenols (µg/g)	500-700	350-500	150-250
Antioxidant activity (%)	80-90	65-75	35-45

(Manikantan *et al*., 2015a)

Techno economic details

Machineries required	Coconut dehusker, Coconut desheller, Coconut testa removing machine, Coconut pulverizer, Milk expeller, VCO cooker, Vacuum dryer, Packaging system, Weighing

	balance, Miscellaneous items such as stainless steel containers, stainless steel containers with trolley attached and other vessels, electrical fittings, electrical water heaters etc
Total investment on machines for processing 500 nuts /day	Rs.15 lakhs (Hot process) Rs.12 lakhs (Fermentation process)
Unit Production Cost	Rs.420 per litre
Breakeven Period	103 days
Net profit percentage	47.17%
Production details per year	VCO – 7500 litres (20% of kernel weight) Milk residue – 7500 kg VCO Cake – 1500 kg Testa – 1000 kg Husk – 60000 kg Shell – 20000 kg Water – 15000 litres

c. Coconut chips

Coconut chips are ready-to-eat, snowy white crisp and healthy non fried snack prepared from fresh kernel through osmotic dehydration in a forced hot air electrical dryer at 70-80°C for 5-6h to less than 3% moisture content. The kernels undergo paring, blanching, slicing and osmotic dehydration to prepare ready to eat chips. It contains 46% carbohydrate, 1.24% protein, 48% healthy fat, 6.13% fibre and 1.36% minerals. Frying is not undertaken in coconut chips making process. Using the method of drying on the basis of osmosis, in which partial dehydration in sliced form is brought about by dipping the fresh kernel in sugar solution followed by hot air drying. This is claimed to result in product with better flavour than freeze drying method at comparatively lesser cost. Hence, the resultant coconut chips give health promoting substances and do not pose any health hazard. Nutraceutical and medicated coconut chips can also be made by incorporating juice of beet root, carrot, ginger and pepper.

Fresh kernel of 8-9 months old coconut is to be used for making chips. Here, the index for selection of the nut is that the nut should be matured enough to be sliced. If it is too tender, slicing and testa removing is not possible. Important steps involved in the production of coconut chips is given below,

Fig. Process protocol developed for the production of coconut chips

Techno economic details

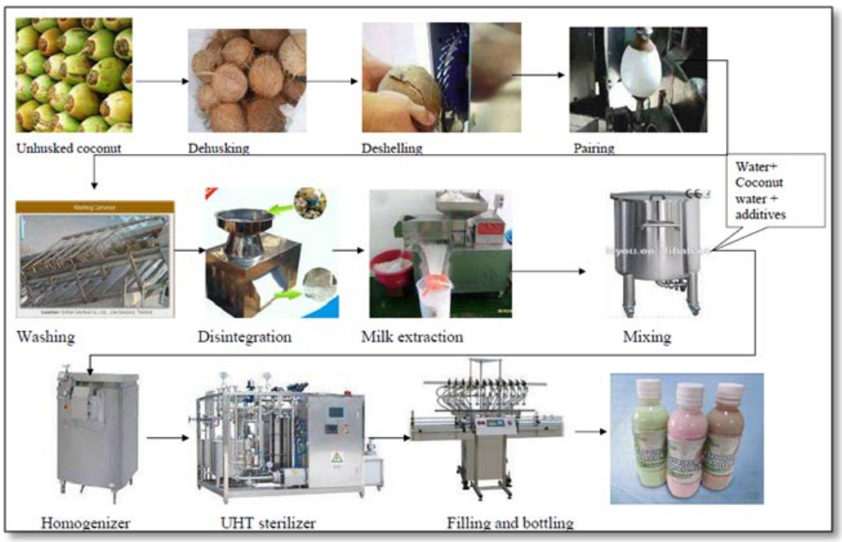
Machineries required	Coconut dehusker, coconut desheller, coconut testa removing machine, multi commodity coconut slicer, blanching unit, plastic basin, filter, muslin cloth, vessel, gas stove, stirrer, solar dryer, electric dryer, heat sealing machine etc.
Capacity	250 coconuts per day
Total investment on machines	Rs.6 Lakhs
Unit Production cost	Rs.8.45 / packet of 25 g
Breakeven Period	56 days
Net profit percentage	57.71
Production details per year	Chips – 11250 kg Husk – 30000 kg Shell – 10000 kg Testa – 500 kg Water – 7500 litres

(Manikantan *et al*., 2015$_b$)

Fig. Coconut chips

d. Coconut flavoured milk

Coconut milk is vegan alternative to dairy milk. Coconut milk does not contain lactose and is lower in carbohydrates than dairy milk, which can be consumed by people who are lactose intolerant or just don't enjoy the taste of dairy milk. Milk is extracted from freshly grated coconut of 9-10 months old. Extracted milk is clarified to remove suspended solids which are present in the milk. Coconut milk is then mixed with coconut water and diluted by adding purified drinking water until it is appropriate for flavoured coconut milk production. It is then mixed with 10-12% sugar, 2% stabilizers, emulsifiers and flavours. The flavoured coconut milk is then UHT sterilized at 138-140°C for about 15 seconds, which is then packed in sterilized polypropylene bottles



(Source: http://coconutboard.nic.in/process.htm)

Fig. Flow chart of Flavoured coconut milk processing

Techno economic details

Machineries required	Dehusking, deshelling, testa removing, blanching, pulverizing, milk expelling, filtration, mixing, Agitation, Homogenization, UHT sterilization.
Capacity	5,000 coconuts/ day
Yield	4000 litres flavoured milk
Cost of plant and machinery	Rs.132 lakhs
Total project cost	Rs.2.23 crores
Pay back period	4.5 years
Internal rate of returns	19%
Break even point	49%

(Source: Coconut Development Board)

2. Products derived from mature coconut water

The water obtained from the mature coconut is usually disposed after dehusking, while the kernel is used for production of coconut oil or coconut milk. Until recently, mature coconut water has been considered as waste, especially in coconut processing plants.

The water when taken out from the nut spoils within a day because of external contamination by microorganisms, which is in the order of 10^6 cfu/ml in the traditional way of collection. Minerals catalyze lipid oxidation and results in free fatty acid (FFA) formation that affects the aroma and the quality of either fresh or processed coconut water. Even if the coconut water is extracted aseptically, its exposure to air initiates oxidation promoted by polyphenol oxidase (PPO) and peroxidase (POD), which are naturally present in coconut water (Duarte *et al*., 2002). Minerals and electrolytes in coconut water also catalyze lipid oxidation and formation of volatile compounds. Hence, it is recommended that the storage temperature for processed coconut water should not exceed 4°C. Addition of ascorbic acid inhibits the activity of PPO and POD in coconut water. There is a scope for processing of mature coconut water into different commercially feasible value added products.

a. Coconut vinegar

Coconut vinegar is the resultant product of alcoholic and acetic fermentation of sugar enriched coconut water. Coconut water can be converted into vinegar by using vinegar generators. The matured coconut water consisting of 1-3 per cent sugar is concentrated to 15 per cent level by fortifying with sugar after filtration. The pasteurized mixture is then cooled and inoculated with active dry yeast *Sacharomyces cerviseae* (1.5g/Litre). After alcoholic fermentation for about 5 to 7 days, the clear liquid is siphoned off and inoculated with mother vinegar or starter culture containing *Aceteobactor* bacteria. This acetified vinegar is then aged before bottling. The vinegar generator assembly comprises a feed vat, an acidifier and a receiving vat for collection of vinegar. Vinegar has extensive use as a preservative in pickle industry and flavouring agent in food processing sector. It is rich in vitamins and minerals such as calcium, phosphorous, iron, sodium and also found to have anti inflammatory and anti microbial properties.

Techno economic details

Machineries required	Feed trough, vinegar acetifier ,receiving trough, wooden storage drums
Capacity	100 litres coconut water/ day
Yield	100 litres vinegar
Land	25 cents
Total Project Cost	Rs. 6 lakhs
Building (Area - 750 sq. ft.)	Rs.3.0 lakhs
Plant & Machinery	Rs.2.5 lakhs
Preliminary & pre-operative expenses	Rs.0.25 lakhs

Contingencies	Rs.0.20 lakhs
Margin money for working capital	Rs.0.25 lakhs
Annual sales turnover	Rs.4.0 lakhs
Net profit	Rs.0.8 lakhs
Return on investment	20 per cent

(Source: Coconut Development Board)

b. Nata-de-Coco

Nata de coco is a translucent gelatinous product prepared from matured coconut water by the action of cellulose forming bacteria namely *Acetobacter aceti* subspecies *xylinium. Acetobacter xylinum* metabolizes glucose in coconut water that act as carbon source and converts it into extracellular cellulose as metabolites. The organism can be cultured either in coconut water or skimmed coconut milk. (Hagenmaier *et al*., 1974). It is widely used in desserts and confectioneries especially in ice creams and fruit cocktails. It is much appreciated for its high dietary fiber, low fat and zero cholesterol content. Because of the high fiber content, it helps to clean human intestine and prevent constipation.

Coconut water is strained and mixed with sugar and glacial acetic acid in stipulated proportions (for every litre of coconut water, 100 g of refined sugar and 5 g of monobasic ammonium phosphate is added). It is then boiled for ten minutes and cooled. Then, add *Acetobacter xylinium* culture solution (150 ml) along with glacial acetic acid (10 ml) and fill in glass trays or wide mouthed jars covered with a muslin cloth and keep for 2-3 weeks without any disturbance. During this period, a white or cream coloured jelly-like substance forms and floats on top of the culture medium. At this stage, the jelly-like substance or Nata willd be about an inch thick. Harvest this surface growth; slice into cubes, approximately 1x3 cm or according to requirement. Then, wash it thoroughly to remove the acid taste smell. Drain the nata and equal quantity of sugar is added, mix thoroughly and keept overnight. Next day, stir the mixture to disperse any undissolved sugar. Add small amount of water. Heat the mixture to the boiling point with occasional stirring. Any flavour material can also be added at this stage. Keep the mixture overnight and repeat the heating process until the nata is fully penetrated with sugar as evident by the clear and crystalline appearance of the sweetened nata and preserv in either tin containers or bottles. Optimum temperature for nata production is in the range of 23-32°C.

The gelatinous growth is believed to be composed mainly of polysaccharides, probably dextrose and cellulose in nature. Nata-de-Coco is a very delicious dessert item in the Philippines and other countries, particularly in the United States, which is served either mixed with other fruits or baked into a delicious cream pie or simply served with flavoured syrup.

Techno economic analysis

Capacity	100 litres mature coconut/ day
Land required	5 cents
Building	Rs. 2 lakhs
Equipment/glasswares	Rs.0.5 lakhs
Yield	20 kg Nata-de-coco
Annual sales turnover @ Rs.40 / kg	Rs. 3.75 lakhs
Net profit	Rs. 1 lakh per annum
Return on investment	40%

(Source: Coconut Development Board)

3. Products derived from tender coconut water

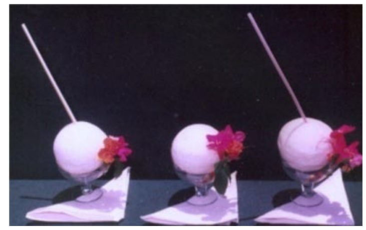
Tender coconut water is the liquid endosperm, and is the most nutritious beverage that nature has provided for the people of the tropics to fight the sultry heat. It has a calorific value of 17.4Kcal per 100 g of water. It contains water (95.4%), protein (0.1%), fat (<0.1%), mineral matter (0.4%), carbohydrates (4.0%), calcium (0.02%), phosphorous (<0.01%) and iron (0.5mg/100g) (Fife, 2011).

a. Minimal processing of tender coconut

Once the tender coconut is detached from the bunch, its natural freshness will get lost within 24 to 36 hours even under refrigerated conditions unless treated scientifically. The bulkiness of tender coconut is due to the husk which accounts for two-third of the volume of tender nut. (Haseena *et al.*, 2010). Technologies for minimal processing of tender coconut have been developed by Kerala Agricultural University (KAU) for retaining the flavour and to prevent discolouration. The process involves dipping (partially) dehusked tender coconut in a solution of 0.50% citric acid and 0.50% potassium metabisulphite for three minutes. The product can be stored up to 24 days in refrigerated condition at 5-7°C. By using this process, tender coconut can be transported to distant places and served chilled like any other soft drink. Optimized uniform size facilitates using of plastic crates and insulated chill boxes for transporting and storage.

In Thailand, young coconut is trimmed, treated with1-3% sodium metabisulphite and packaged with opener, straw and spoon. These are commercially produced, marketed and exported. The shelf life of the processed young coconut is 45 days in 3-6°C or 3 weeks in 7 – 10°C.

b. Snow ball tender coconut



Snow ball tender nut is a tender coconut without husk, shell and testa which is ball shaped and white in colour. This white ball will contain tender coconut water, which can be consumed by just inserting a straw through the top white tender coconut kernel. Seven to eight months old nut is ideal for making snow ball tender nut in which there is no decrease in quantity of tender nut water and the kernel is sufficiently soft. The technology for preparing snow ball tender nut (SBTN) has been developed at ICAR-CPCRI, Kasaragod. This is served in an ice cream cup. The user can drink the tender nut water by piercing the kernel with a straw. After drinking water, the kernel can be consumed using a fork. The coconut water is not exposed to the atmosphere and is natural and sterile.

The machine consists of a circular blade having 24 teeth of 8 mm width that rotates at a speed of 1440 rpm. The prime mover of the machine is a 0.5 HP single phase electric motor. The prime mover attached with the circular blade is fixed on an angle iron frame with a covering made of mild steel sheet. A stop cutter box of stainless steel with a clearance of 15mm is used to cover the circular blade. The adjustable stop cutter box helps the user to control the depth of cut and protects the user from possible injury while operating the machine. A flexible knife known as scooping tool also has been developed for scooping out the tender nut kernel from the shell. The scooping tool is made of nylon and is flexible at one end. The scooping tool is inserted in between the kernel and shell through the groove and is rotated slowly to detach the entire kernel from the shell.

c. Packaged tender coconut water

The Coconut Development Board (CDB) in collaboration with the Defence Food Research Laboratory (DFRL), Mysore has developed a technology for preservation and packing of tender coconut water aluminum cans/ pouches with a shelf life of three months under ambient conditions and six months under refrigerated conditions. Apart from that, a tetra pack technology has also been established in Tamil Nadu. The products are available in both domestic and international markets. Major exporters of the product are Philippines, Indonesia, Malaysia and Thailand (Muralidharan and Jayashree, 2011).

Techno economic details

Machineries required	Mechanical washing system with conveyor, automatic boring and sucking system, ss filter / clarifier, collection tank, treatment tank, pasteurization unit, boiler, filling and sealing machine, shrink wrapping machine, air compressor, coding machine
Capacity	5000 coconuts / day
Total project cost	Rs.131.4 lakhs

Plant & Machinery cost	Rs.65 lakhs
Internal rate of return	18%
Breakeven point (sales)	51%

(Source : Coconut Development Board)

d. Tender coconut water jelly

Tender coconut water is a suitable option for the preparation of jelly as its delicate flavour can be well preserved in the form of jelly. The ingredients such as tender coconut water, sucrose and solidifying agent (china grass) are needed to prepare jelly. The standardized quantity and concentration are tender coconut water 1L, sugar-150 g (15% of tender coconut water) and china grass- 10g (1% of tender coconut water).

Tender coconut water is heated in a sauce pan with sucrose and china grass. Care should be taken to continuously mix the content during heating with a stainless steel spoon/ ladle to melt the china grass in the tender nut water. Once it is completely melted, remove from the heat, cool it and pour in a wide mouth vessel/ tray and keep inside the refrigerator for about 3 hrs to solidify. After solidification, cut the pieces in cubes or squares and serve along with ice cream/ any other desserts as toppings.

4. Products derived from coconut inflorescence sap

Coconut sap popularly known as neera is highly prone to fermentation, and collection of unfermented sap is a challenging task. This has been resolved with the development of CPCRI developed ‘Coco sap chiller’. The sap collected by coco-sap chilller at low temperature is observed to be entirely different from the neera collected by traditional method with or without preservatives; hence, it was christened as “Kalparasa”. Sap collected using the coco-sap chiller is golden brown in color, delicious and free from contaminants like insects, ants and pollen as well as dust particles.

Coco-sap chiller is a portable device characterized by a hollow PVC pipe of which one end is expanded into a box shape to house a sap collection container bound by ice cubes and the other end is wide enough to insert and remove a collection container of 2 to 3 litres capacity. Each side wall of the pipe from outside is covered with an insulating jacket excluding the portion of spadix holder which retains the internal cool temperature for a longer period. This coco-sap chiller is lighter in weight, water proof, easy to connect to the spadix, requires less ice and retains low temperature for longer period as compared to commercially available ice boxes (Hebbar et al., 2015).

Kalparasa collected by coco-sap chiller under low temperature meets the Codex Alimentarius (International Food Standards WHO/FAO) definition of juice as “unfermented but fermentable juice, intended for direct consumption, obtained by the mechanical process from extractable fluid contents of cells or tissues, preserved exclusively by physical means”. Thus, it is amenable to be sold as fresh juice under local market with the adherence to quality standards prescribed by CPCRI. It does not require lot of machineries but requires cold chain or refrigerated system

Quality attributes of sap

Distinct differences are noticed between the sap collected by traditional method and CPCRI technique (Table 2.).

Table 2. Quality attributes of sap collected by CPCRI technique and traditional technique

Attribute	CPCRI Technique	Traditional technique
Soluble solids (°Brix)	15.5 to 18	13 to 14
pH	7 to 8	6 or low
Colour	Golden brown or honey	Oyster white
Defects, decay, insects, pollen, dust	Absent	Present
Flavour	Sweet and delicious	Harsh odour
Pathogens, chemicals and extraneous matter	Absent	Present
Microbial load	Low	High

Storage: The collected sap can be stored for any length of time under sub-zero temperature. Deep freezers are used for the purpose. The sap gets freeze and just before use it is thawed to get the original liquid form. However, under refrigerators the quality gets deteriorated within few hours.

Techno economic details

Machineries/ devices required	Tapping gear (knives, tapping stick, scissor, mallet etc), o-sap chillers, neera collection ice box, ice carrying box, ph meter, measurement jug, neera storage container, neera transport box, freezer, neera dispenser etc.
Capacity	1000 liter of sap per day
Capital investment	Rs. 35,10,200
Operational cost per month	Rs. 75,875
Total cost of production	Rs. 1,06,91,785
Total sap production (l)	Rs. 3,65,000
Selling cost	Rs. Rs 50/ l
Unit cost of production	Rs. Rs. 29/l
Breakeven period	Rs. 176
Net profit %	Rs. 41.41

Coconut Sugar

The hygienic, zero alcoholic sap collected by CPCRI method is easy to process in a natural way without the use of chemicals into various value added products which fetches premium prices both in domestic and international markets. Very good quality coconut sugar, jaggery, nectar or syrup can be produced in double jacketed cookers with temperature regulation and stirring facility.

Coconut sugar is the best natural sweetener with several health benefits and thus has a high market potential. It contains all essential amino acids required for protein synthesis; contains considerable amount of minerals like calcium, magnesium, zinc, iron and copper; rich in electrolytes like sodium and potassium; abundant in dietary fibers which normalizes bowel movements and digestion; rich source of phenolics which are potent and important contributors in reducing oxidative stress due to their antioxidant activity. Moreover its glycemic index (GI) is low in the range of 35 to 54 GI/ serving and eating a low glycemic index diet reduces the risk of chronic diseases such as Type 2 diabetes.

Fig. Coconut sugar

Techno economic details

Labour cost	Rs. 5,04,000
Total fixed cost	Rs. 20,19,975
Total variable cost	Rs. 1,01,72,500
Total cost of production	Rs. 1,21,92,475
Total sugar production (kg)	Rs. 54,750
Selling cost	Rs. 275/kg
Unit cost of production	Rs. 223
Breakeven period	Rs. 150
Net profit %	20

Conclusion

Coconut has the greatest importance in the national economy as a potential source of employment and income generation among the plantation crops. The demand for coconut is high because of its usage and the adaptability of coconut palm to grow under various climatic and soil conditions. With the use of coconut oil in the production of soap and margarine in Europe in the 19th century, it was converted into a commercial crop. In the beginning of 20th century copra was the king among the oil seeds. In East Indies it was known as green gold. However, the period after the Second World War saw the substitution of vegetable oils and oleo chemicals for coconut oil in international trade. Price of coconut oil fluctuated heavily due to frequent short supply situations. A campaign against coconut oil alleging that it causes cardiovascular diseases aggravated the situation. The newly industrialized countries in the East such as Taiwan, South Korea are fast emerging as key importers of coconut product. One of the main reasons for the fall in price of the coconut and its products is dependency of price of coconut oil which again depends on the cost of other vegetable oils. Thus, product diversification of coconut and development of value added products become very important in the coconut industry. Effective market promotion activities are also to be organized by way of organizing exhibitions, workshops and trade fairs in order to create consumer awareness and boost the demand of coconut products to keep the wheel of the coconut industry moving fast for doubling the income of coconut farmers for their sustainable livelihood.

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Soil and Water Conservation Practices for Coconut Gardens in Hilly Agro-Eco Systems

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Introduction

The mountainous regions of India are different from the rest of the nation due to its unique ecology, topography, climate, culture and people. The traditional hill agro-ecosystems in the country are endowed with a bounty of water resources and they are considered to be more sustainable from an ecological point of view. These regions are in the highest rainfall zone of the country and enjoys typical monsoon climate, with conditions ranging from tropical to temperate. But over the past several years there has been tremendous pressure upon these natural resources due to several forces including industrialization, urbanization, and unprecedented human growth. Delay in pre-monsoon showers and slow onset of monsoon along with skewed distribution of rainfall not only leads to serious dislocations, but also causes damage to the crops and also severe water shortage. On the other hand, excessive precipitation causes rapid run-off on steep slopes, resulting in heavy soil loss as well as siltation of valleys and riverbeds. The efficient utilization and management of available rainwater is the core issue if the cropping intensity and production is to be enhanced and therefore dealt in detail. Apart from these the erosion control and landslide combating practices, which are also inevitable and potentially inclusive to the water management practices in hilly region, are also covered.

Characteristics of coconut in relation to water need

Some of the unique features of coconut palm, in comparison with other trees and annual crops, necessitate the maintenance of optimum soil moisture throughout the year to grow well and yield high. The coconut palm flowers throughout the year, irrespective of seasons. On an average, a palm produces one frond, with an inflorescence in its axis, every month and 12-15 inflorescences are produced in a year. It takes 44 months for an inflorescence bud to grow and develop to produce mature nuts. Since a palm produces an inflorescence every month, its crown will have inflorescences at different critical stages of development throughout the year. Hence soil moisture availability, as well as other growth conditions, should be congenial throughout the year for high productivity in coconut.

Agronomical practices for managing soil and water

Agronomical interventions are mainly based on cultivation practices. Most of these practices yield dual benefits- soil conservation and water management including in-situ conservation and groundwater recharge. The major agronomical measures, which can be adopted in hilly terrain of the country, are listed below:

1 Contour cultivation: In sloppy areas, chances are more for loss of topsoil along with water. To prevent this, cultivation in hilly areas should be done only across the slope, along contours. Adoption of this method helps to retain soil and water in each contour and prevent its losses.

2 Cover cropping: Growing cover crops in wastelands and cultivated fields helps to cover the soil. Because of this, raindrops will be falling on the leaves of these cover crops and thus reduces the impact of it on the soil and protect from splash erosion. The cover crops also help to reduce the growth of weeds and minimize the loss of soil moisture due to evaporation. They will also add fertility to the soil on decomposition. *Peuraria, Calapagonium, Centrosema, Mucuna,* and *Mimosa* are some of the ideal cover crops that can be grown for this purpose. It is noticed that these crops, on an average can give around 5 tonnes of biomass from one hectare of land.

3 Mulching: It is a common practice in many areas to burn all the fallen leaves, crop residues and other waste materials in the field. As this is not very ideal, it is recommended to use them as mulch between and around the plant basins. Mulches will cover the soil and reduces the loss of soil moisture especially during dry periods. It will also help to reduce soil erosion during rainy time and improves soil fertility after decomposition. Thick mulching will also help to reduce the quick depletion of soil humus due to fast decomposition in tropical regions.

4 Grass cropping: Cultivation of suitable grasses in areas prone to soil erosion helps to minimize the loss of soil. This method is not only economic, but also help to produce sufficient fodder materials when cattle rearing are also undertaken. Raising of fodder grasses on the contour bunds and soil bunds will enhance the life of such structures. It is ideal for sloppy lands.

5 Crop rotation: Continuous cultivation in sloppy lands with crops that enhance soil erosion will lead to more soil loss. Repeated cultivation of same crop in an area is not ideal due to many reasons. This will lead to depletion of soil nutrients over the years and also lead to build up of some pest and disease problems. Hence after the harvest of one crop, another crop of different nature is to be raised in the same field. This will help to become a cover to the soil and helps to reduce soil erosion and add organic matter on decomposition. Cow pea, Ground nut, Sweet Potato or Vegetables can be grown after harvesting of upland paddy in such areas.

6 Strip cropping: Soil and water conservation is possible by strip cropping in areas with slopes. Ribbon-like Strips with more length and less width can be made for cultivation along contour lines. This method of cultivation can be adopted across the slopes in areas when crops that cause soil erosion are to be raised. Upland paddy, cowpea, fodder grasses, vetiver etc. are ideal for strip cropping. Depending on the intensity of slope, trenches can be made at intervals of 3 to 7 m along the contours and water conservation can be made more effective. These kinds of trenches and different crops raised on strips will help reduce soil and water loss to a considerable extent.

7 Conservation agro-forestry: Planting ideal tree species in combination with agricultural crops help to prevent soil erosion in slopping lands. Trees having timber value such as Teak, Artocarpus etc and others like Cashew, Amla, Neem and Silver Oak can be grown in this manner.

8 Multi storied cropping system: This system makes efficient use of difference in height of component crops above ground and the spread of root system below ground. In this method, crops requiring more sunlight form the upper canopy, while those requiring less light occupy the lower canopy. Because of this arrangement, competition for sunlight is reduced to the minimum. Crops selected should also have different rooting behaviour and root system. This helps to forage different soil layers for plant nutrients as well as moisture and enhance soil fertility due to decomposition of fallen leaves. Apart from reduction in soil loss and runoff, it is also possible to increase net income per unit area of land.

9 Integrated farming or mixed farming: This approach aims at appropriate integration of all those agricultural and non-agricultural enterprises that can be adopted and practiced in an area. The main or by-product of one crop or agricultural practice is made use as basic resource for another activity or enterprise. In a system, raising banana, pine apple, fodder grass and cow pea in an area helps to produce necessary feed material for cattle, piggery, apiary and pisciculture. Recycling of bio mass maintains soil fertility and eventually brings higher net return for the system as a whole.

Engineering Measures for managing soil and water

The topography of major mountainous regions in the country comprises mainly undulating steep slopes, moderately sloping lands and flat lands. Increase in pressure on land and lack of fertile flat land for cultivation force the people to cultivate on steep slopes. Cultivation on steep slopes is practicable only by providing intensive soil and water conservation measures, which include structural/engineering measures. The major structural/engineering measures are as follows:

1 Contour bunds: They consist of building earthen enhancements across the slope of the land, following the contour as closely as possible. A series of contour bunds divide the area into strips and act as barriers to the flow of water, thus reducing the amount and velocity of runoff. When bunds are constructed strictly on contour lines, it will hold the entire water coming from the interspaces between two successive bunds and the water stored will gradually infiltrate into the soil which in turn helps in replenishing soil moisture and ground water storage. In addition, the eroded soil will be deposited behind the bund.

2 Terracing: Bench terracing consists of transforming relatively steep land into a series of level or nearly level strips running across the slope. These strips are separated by vertical risers. Terraces are favoured on slopes steeper than 15% and where fertile deep soil is available.

The use of terraces on steep slopes not only retards erosion losses but also makes cropping operations on these lands possible and safe. Terracing may be a) level/table top, b) sloping outward or c) sloping inward.

3 Intermittent terraces (platforms): Intermittent terraces are suitable on steep slopes (>42 percent), where only plantation crops/forest species are grown. The entire sloping land is not converted into step like terraces but only the crop rows are terraced following contours. In the sloping interspaces between two intermittent terraces, usually cover crops are grown. Intermittent terraces are usually constructed with an inward slope so as to conserve the entire rainfall received.

4 Moisture conservation pits (catch pits): Small pits can be constructed across the slope to harvest rainwater. Eroded soil will be deposited in the pits and water collected will be gradually infiltrated into the soil thus increasing the moisture regime of agricultural land. They are suitable in between plantation crops/forest species grown on flat and slightly sloping lands. Pits of size 1.5 m x 0.6 m x 0.6m may be constructed at suitable intervals according to the site conditions. This practice is not recommended in steep slope areas, where possibilities of land slide hazards are more.

5 Crescent platforms/bunds: Whenever plantation crops or tree species, which do not require frequent intercultural operations, harvesting etc, are grown on steep slopes (> 42 percent), inward sloping terraces can be taken around each tree usually in half moon shape. Such terraces are known as crescent platforms. Cost of construction, soil disturbance etc can be reduced significantly in this system compared to bunding or terracing.

6 Contour trenches: They are narrow trenches built along contours for collecting and draining overland flow as well as for increasing soil moisture. They can be constructed continuously across the slope or in a staggered manner. Contour trenches are suitable on steep slopes where perennial crops are grown with less interspaces. They are also recommended in wastelands for intercepting overland flow.

7 Check dams : Check dams are embankments constructed across the flow of water. They can be either made of locally available materials like brushwood, loose rocks, sand bags, plants etc. or a RCC/masonry/ferrocement structure. The major uses of a check dam are:

- To reduce the gully bed slope thereby reducing the velocity of runoff water, preventing the eroding and down cutting of gully beds.
- To encourage the deposition of silt and create favourable soil moisture regime for the establishment of plant cover.

Where stones or rocks of appreciable size and suitable quality are available, they may be used to make check dams in gullies that have small to medium size drainage areas. Loose rock/boulder check dams reinforced with vegetative measures will form a very effective barrier against the flow of water. Such structures can be strengthened by encasing in woven wires called Gabion structures.

Brush wood check dams are low cost structures that can be constructed across streams in such locations where the velocity of runoff is not high. Poles of bamboo, pine, arecanut, casuarina etc. may be fixed in two rows across the drain and the space in between the poles is filled with waste materials such as coconut leaves, jungle wood etc. The poles fixed are tied together with few poles placed across them using G.I. wire so as to form a stable structure. A chain of check dams at the head or middle reached of a mountain stream may help to harvest water and reduce stream bank erosion.

8 Vegetative filter strips: In places where runoff water is coming from upper hill areas in considerable volumes, bunds of height 15 cm to 45cm can be constructed across the slope and pineapple, vetiver and other grass strips can be established to filter the runoff and to prevent soil loss.

9 Ponds: Ponds are common structures used for rainwater harvesting. New ponds can be constructed on the sides of the drainage line. Side protection works such as rubble walls/stone pitching etc. can be done.

The existing ponds can be renovated by desilting and strengthening sides with vegetative or structural measures. In addition, stone quarries left in the field after cutting can be effectively used for collecting runoff water by constructing suitable diversion drains.

Rainwater can also be collected in large quantity in lined ponds. Generally big ponds are constructed and subsequently lined with non-permeable sheets like Agrifilm, Silpaulin or HDPE or with a semi-permeable coating of clay to reduce the seepage losses.

10 Percolation tanks: These ponds/tanks are used to collect rainwater or runoff and aid in deep percolation and thereby groundwater replenishment.

Apart from these many other structures such as gulley plugs, nala bunds, earthen dams, spillways, weirs etc. can be used for drainage line treatment in hilly areas. Geo-textiles (coir, Jute etc.) or certain species of crops (vetiver, grass etc.) can be used to cover soil and thereby arrest the amount of soil erosion. They also filter out the silty runoff water and promote its soaking into the soil. The suitable soil and water conservation practice/structure should be selected and further designed based on factors such as the amount of rainfall, run off, topography, vegetation, type of soil, and socio-economic considerations.

In-situ soil and water conservation measures specific for coconut gardens

1. Mulching coconut basins with leaves, coir pith etc.

Mulching the coconut basin helps to reduce soil temperature and evaporation from soil surface. Mulching can be done with slashed weeds from the inter row, coconut husk and coir dust or by any organic material that can be found in and around the plantation. Coconut husks can hold moisture to the tune of three to five times of its weight. Approximately 250 to 300 husks required for one coconut basin. Mulching is usually done upto a radius of 2 m. Two layers of husk may be buried in the coconut basin with the concave side facing upwards. These layers facilitate absorption of moisture. Above this another layer of coconut husk is placed with the convex side facing upwards to arrest evaporation. Effect of mulching lasts for about 5-7 years.

2. Coconut husk burial in the interspaces of coconut garden

Husks, if buried in the soil act as a water reservoir and also supply palms with small amount of potash present in it. A fully soaked husk is able to retain about 5-6 times of its weight of water and is made available to the palms during summer season. Trenches of 50 cm width x 50 cm depth and convenient length would be made in between two rows of coconut palms. These trenches would then be filled with coconut husk. Coconut husks need to be filled in layers with the bottom layers facing up and top layer facing down. A bund of 20 cm height and suitable width (>50 cm) is made at the downstream using the excavated soil. Two layers of pineapple plants would be planted on the bund with a spacing of 20 cm plant to plant and 20 cm row to row. Pineapple plants would stabilize the bund and provide additional income to the farmer. The runoff water from the upper side would be collected in the trenches. Soil particles would also get collected in the trench along with the runoff water.

3. Half-moon bund around coconut basin reinforced with pineapple

This measure is to be taken up where there is mild slope (15-20%). Here a flat basin with a slight inward slope towards upstream is made by excavating soil from the upstream side and filling the excavated soil at the downstream side. After making the basin a bund of 30 cm height and >50 cm width is made at the downstream side of the coconut using the excavated soil. Two layers of pineapple plants would be planted with a spacing of 20 cm row to row and 20 cm plant to plant on the bund. The bund prevents runoff and water gets collected within the basin and percolates down. Pineapple would help to protect the bund and stabilize the same in addition to giving fruit yield.

4. Trench filled with coconut husk

This measure is to be taken up where the land slope is high. Trenches of 50 cm width x 50 cm depth and convenient length would be made in between two rows of coconut palms. These trenches would then be filled with coconut husk. Coconut husks need to be filled in layers with the bottom layers facing up and top layer facing down. A bund of 30 cm height and suitable width (>50 cm) is made at the downstream using the excavated soil. Two layers of pineapple plants would be planted on the bund with a spacing of 20 cm plant to plant and 20 cm row to tow. Pineapple plants would stabilize the bund and provide additional income to the farmer. The runoff water from the upper side would be collected in the trenches. Soil particles would also get collected in the trench along with the runoff water. Coconut husk retains the moisture and makes it available for plants during summer months.

5. Catch pits with pineapple border

Catch pits can be constructed at all slopes to conserve soil and water. Though there is no standard dimension for catch pits, we may go for catch pits of 1.5 m length x 0.5 m width x 0.5 m depth. A bund is to be made at the downstream using the excavated soil and pineapple plants planted on it. This pit also may or may not be filled with coconut husk. If it is without husk, periodic measurement of the dimension of the pit gives the amount of soil collected inside the pit, a direct measurement of soil erosion.

6. Cover crops as green manure and to reduce soil erosion

Crops like calopogonium, peuraria, cowpea etc., can be grown as cover crop in coconut gardens where mild to steep slopes are prevalent. Growing of cover crops protects the soil from beating effect of rain especially during high intensity of rainfall thus helping in the percolation of the rainwater. This also helps in preventing the soil as well as nutrient loss.

Conclusion

The basic aim of in-situ soil and water conservation planning is to achieve sustainable development through the scientific management and utilisation of locally available natural resources in their natural boundaries without adversely affecting the ecological balance. Farmer-to-farmer extension is a key process for passing information to the catchment's inhabitants, for closer collaboration between farmers and for scaling-up water conservation in neighbouring watersheds. Technologies selected depend on the individual needs of farmers. Flexibility is ensured from the planning and design to execution. Emphasis is on sustainability and equity rather than on short-term benefits.

Doubling farmers income through Coconut Based Integrated Farming – Economics and marketing aspects

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Introduction

Sustainable livelihood of coconut farmers is a contemplated issue ever since we have started experiencing the price stagnation of coconut. Realizing the fact that unilateral increase in productivity is not the sole solution for livelihood crisis in the sector (Harilal, 2010; Jayasekhar *et al*., 2014), it is the time that we need to act proactively on other possible alternatives in the sector. For brightening the future prospects of a sustainable coconut sector, it is imperative to delink the sector from the dependency on coconut oil and enhance the production of diversified value added products. Further, to ensure the livelihood security of those dependent on the sector, it is of paramount importance to strengthen the value chain of the coconut through appropriate forward and backward integration of the chain. As a matter of fact coconut has wide range of food products traded across the world, but India lags behind in product diversification. It is noteworthy that the nutraceutical and therapeutic qualities of coconut are not well acknowledged in India. The value chain aspects of the coconut had been thoroughly neglected and only in the very recent times this aspect began to attract the attention of researchers and policy makers. Nevertheless, there exists a huge scope for coconut based agri-business in India in order to increase the present 8% level of value addition to 25%, thereby value added products steer the price movement of coconut to ensure fair, reasonable and steady price to coconut farmers. Technologies are available for individual processing for the production of snowball tender nut, neera, coconut chips, copra, vinegar, desiccated coconut (DC) coconut shell charcoal, packed tender nut water, coconut cream and milk powder. Fairly high level of capital is required for establishment and operation of these enterprises (Sairam *et al.*, 2008). For this institutionalized credit may be arranged through developmental agencies especially. A huge amount of returns will, act as the motivating factor. Further coconut farmers are expected to realize better price stability in long run.

Global and National Scenario

Among the plantation crops, coconut palm is the major crop grown both under plantation and homestead management system. It provides livelihood security to several millions of people across the world, and capacity of coconut in providing improved nutrition, employment and income generation are well known India stands 3rd in world area of coconut and first in production with the share of 17 per cent and 31 per cent respectively (Table 1). Indonesia holds largest area in coconut (29 per cent) followed by Philippines. As far as the productivity is concerned Brazil holds the highest figure (11630 nuts/ha) followed by India (10119 nuts/ha).

Table 1. Area and production of coconut in the world (2013-14)

Country	Area ('000ha)	% share	Production (million nuts)	% share	Productivity (nuts/ha)
Indonesia	3610.0	29.6	16354.0	23.4	4530
Philippines	3502.0	28.7	14696.0	21.1	4196
India	2141.0	17.5	21665.0	31.0	10119
Sri Lanka	440.0	3.6	2870.0	4.1	6523
Brazil	251.0	2.1	2919.1	4.2	11630
Papua New Guinea	221.0	1.8	1483.0	2.1	6710
Thailand	206.0	1.7	1001.0	1.4	4859
Others	1825.0	15.0	8848.3	12.7	5662
Total	12196.0	100.0	69836.0	100.0	5777

Source: Asian and Pacific Coconut Community (APCC) Statistical Year Book 2014

India has produced 20439 million nuts in the year 2014-15 from an area of 1.97 million ha with a productivity of 10345 nuts per hectare (Table 2). Tamil Nadu is the major producer of coconut, contributing around 34 per cent of the total production in the country. Coconut is predominantly cultivated in small and marginal holdings in the country. Most of these holdings neither provide gainful employment opportunities for the family labour throughout the year nor generate sufficient income to meet the family requirement. Presently coconut growers are more exposed to economic risks and uncertainties owing to the high degree of price fluctuations. In this context it is needless to emphasize the importance of crop diversification in coconut gardens.

Table 2. Coconut: National scenario

State	Area (000 ha)	Production (million nuts)	Productivity (nuts/ha)
Andhra Pradesh	105.9	1463.5	13808
Karnataka	515.0	5141.1	9982
Kerala	649.8	4896.6	7535
Tamil Nadu	465.1	6917.4	14873
Other States	239.0	1911.0	7295
India	1975.8	20439.6	10345

Source: CDB, 2016

It is imperative to have a look at the international trade scenario of coconut value added product exports. While comparing with other major global exporters, the share of India in coconut product exports is meagre (Table 3). Though it is an accepted fact that, India holds a robust domestic market in the coconut sector, it is high time that we emerge as a major export player by upgrading our position in the global value chain of coconut exports. The Philippines and Indonesia together contributes the major world export share of coconut oil, copra meal and desiccated coconut. Sri Lanka too contributes substantially to the international exports of coconut milk, shell charcoal and coir products.

Table 3. Percentage share of world exports of coconut products

Sl No	Product	Countries (percentage share)			
1.	Coconut oil	Philippines (42)	Indonesia (35)	Malaysia (9)	India (0.30)
2.	Copra meal	Philippines (64)	Indonesia (34)	Others (1.9)	India (0.004)
3	Desiccated coconut	Philippines (25)	Indonesia (20)	Sri Lanka (12)	India (1)
4.	Coconut milk/cream	Indonesia (51)	Sri Lanka (44)	Philippines (4)	India (0.30)
5.	Coconut shell charcoal	Indonesia (70)	Sri Lanka (20)	Philippines (7)	India (0.30)
6.	Coir and coir products	Sri Lanka (42)	Thailand (12)	Indonesia (10)	India (25)

Source: Author’s computation from APCC Statistical year book 2014

The Untapped Potential of value added products

Among commercial coconut products, Virgin coconut oil (VCO) has received much attention globally in the recent times. The demand for this oil continues to rise, which can be attributed not only to its superior flavor, but also to reports of its potential health benefits. Virgin coconut oil is reported to lower the lipid levels in serum and tissues, and possesses high potential in protecting low-density lipoprotein against oxidative stress induced by physiological oxidants. Globally, Philippines is the largest exporter of VCO. Besides the Philippines, other leading VCO exporters are Indonesia, India, Malaysia and Papua New Guinea. Between 2007 and 2012, exports of VCO to the EU showed a strong average annual increase of 55% in terms of volume and 80% in terms of value. While the Netherlands is the largest importer of conventional coconut oil in the EU Germany is the largest importer of VCO in the EU market, followed by Belgium.

The protocols for the production of virgin coconut oil by fermentation, by hot process and by intermediate moisture content method were standardized. Fermentation method is an economically viable technology that can be taken up as a cottage industry, whereas, the other two methods are mostly suitable for small scale industries. Consumer preference studies have shown that there is good demand for VCO but the high cost of the oil than the commercial grade coconut oil and other cooking oils is a limiting factor. Business project proposals were prepared and given to many entrepreneurs. Technology for production of VCO by hot processing and by fermentation was transferred to many entrepreneurs. Feasibility analysis of the project on commercial production of virgin coconut oil revealed a Benefit Cost Ratio of 1.12, and an Internal Rate of Return of 21.5 %. Thereby, we may conclude that the commercial production of Virgin Coconut Oil could turn out to be a profitable venture. Though the market of VCO is expanding in the domestic and International front, as a matter of fact, India is yet to realize the potential benefit that the country holds in this segment. It is imperative to establish good quality, technically advanced VCO units across the country so as to realize the competitive market share of VCO in the global market.

Desiccated coconut is another important commercial product which is rich in healthy saturated fats with no cholesterol and it is an excellent source of dietary fibre. With 30% of the world's imports, the European Union (EU) is the largest importer of desiccated coconut in the world. Imports of desiccated coconut to the world are increasing with the Netherlands, Belgium, Germany and the United Kingdom as the leading importing countries. Over the last five years, imports of desiccated coconut to the world grew by 19% in value and by 4.1% in quantity, which provides opportunities for new suppliers from developing countries.

The Philippines is the main global exporter of desiccated coconut, accounting for more than a third of exports. Though India is the largest producer of raw coconut in the world, Desiccated Coconut export is only to the tune of less than one percent of the global demand. Nevertheless, during the year 2015-16 India exported 4261 MT Desiccated Coconut worth Rs 52.60 Crores. In comparison with the export figure of previous year, India achieved an increase to the tune of 63 percent, which is indeed remarkable. The capital investment required to start up a Desiccated Coconut production unit, of capacity to process 15,000 coconuts per day, amounts to Rs 1.29 Crores. It is noteworthy that there are attractive export promotional schemes initiated by the Government of India in this under the new Foreign Trade Policy (2015-20), wherein under Merchandise Export from India Scheme, five percent export subsidy can be availed on Free on Board (FoB) prices.

Although, Indians have been using coconuts in food and snack preparations since time immemorial, till recent times, desiccated coconut was not used in large quantities in individual households as it has been used in confectionary and biscuit industry. But in recent times due to the fast pace in urban life, there is considerable growth in the Indian confectionery industry (25 percent/ year). It is an indubitable fact that Desiccated Coconut is a high potential breakthrough product, which can bring in a paradigm shift in domestic coconut sector of India.

The ICAR-CPCRI has developed a technology for collecting coconut inflorescence sap by using a device. The sap thus collected is called Kalparasa (Neera)). Kalparasa can be preserved up to 45 days under cold condition (in refrigerator) without adding any preservatives and additives with the bottling technology. It has been demonstrated that a farmer tapping 15 coconut palms for Kalparasa could earn on an average Rs. 45,000 a month, while a tapper can earn about Rs. 20,000 per month.

Coconut based cropping / farming systems

Small and marginal farmers, who are more risk-averse than large farmers, are expected to adopt higher degree of farm diversification or intensification for protection against natural and economic risks. This means that farmers can make use of the production complementarities to reap the benefits of synergism through appropriate choice of crop combinations or other economic activities. This would help them to achieve maximum resource use efficiency through i) intensive use of land, ii) optimum use of time, iii) benefits from additional enterprises, iv) reuse of farm wastes and byproducts, v) rational use of farm family labour and vi) integration of farm and non-farm activities.

As stated earlier coconut farming in India is predominated with small and marginal farmers. In the recent past, the price of coconut products had fallen sharply causing severe economic loss to millions of coconut farmers in India and in particular in Kerala State. The production and price risks involved in perennial crops would have more impact on farmers since they cannot revoke the farm managerial decisions in these systems. One among the ways to overcome this problem is farm diversification and intensification with other annuals, biennials and perennials. The crop scientists have made strenuous research efforts since seventies to evolve different coconut based cropping/farming systems. At the same time, the research on socio-economic aspects of these systems was undertaken at international and national levels.

Though farm diversification and intensification are considered to be a favourable solution to increase the gross farm income, it is essential to assess their economic viability in small and marginal farms. Small-scale diversification of farming by marginal and small farmers need not always generate adequate income for their sustenance. Moreover in the present socio-economic scenario, small and marginal farmers often do not have the ability to invest in additional crop and non-crop enterprises, which require high investment and labour inputs. They also find it difficult to assume risks of adopting any new agricultural economic activity, unless the relative economic gains from such activity have already been demonstrated elsewhere or unless the expected relative profitability from proposed diversification appears to be reasonably favourable in their perception. This is particularly true if the opportunity cost of such proposed diversification or intensification is high. Further experimental results from India and other major coconut growing countries indicated that the annuals, biennials and perennials can be successfully cultivated as inter/mixed crop in coconut gardens.

Field experiment conducted at Coconut Research Station, Veppankulam, in Tamil Nadu State of India during 2004-2010 with an objective of developing a multispecies cropping system model in coconut suitable for East Coast Region of Tamil Nadu. Eight different cropping systems models were tested in 25 years old East Coast Tall (ECT) coconut garden. Among them, the model IV (Coconut + black pepper + banana + E.F. Yam) recorded the highest B:C ratio (2.16) and net income (Rs. 57, 577 ha-1) followed by the model II (Coconut + Banana + Black pepper) where the corresponding values were 20.8 and Rs. 45, 557 / ha. The model III (Coconut + Banana + Black pepper + Bhendi) recorded the highest soil available NPK when compared to other models. The soil nutrient content and soil microbial load of intercrops the model IV

(Coconut + Black pepper + Banana + E.F. Yam) recorded the maximum soil microbial population. Based on the feasibility, marketability and economic viability the model IV is considered as the most suitable intercropping system in coconut for East Coast Region of Tamil Nadu.

S.No	Models/Intercrops	Cropping period	Average yield (kg/ha)	Gross Income (US$/ha)	Cost of Cultivation (US$./ha)	Net Return (US$./ha)	BCR
I	Coconut alone		16643	1073.54	633.60	439.88	1.69
II	Banana+ Black pepper	Jul - May	14520 43.75	1313.81	630.00	683.36	2.08
III	Black pepper + Banana + Bhendi	Jan - Nov	43.75 5270 4500	982.61	602.64	379.97	1.63
IV	Black pepper + Banana + Elephant Foot Yam	May-Mar	43.75 6100 8360	1607.51	743.85	863.66	2.16
V	Black pepper + Banana + Turmeric	June - Mar	43.75 5660 5250	1068.33	696.87	371.46	1.53
VI	Black pepper + Banana + Pineapple	June - May	43.75 5450 3100	869.06	464.55	398.66	1.87
VII	Black pepper + Banana + Tapioca	May – Mar.	43.75 5520 7700	849.86	469.50	380.36	1.81
VIII	Black pepper + Banana + Mango ginger	June – Mar.	43.75 5240 8500	981.60	487.50	494.10	2.01

Estimate from the Source: S. Thiruvarassan, H.P. Maheswarappa and T. Subramani, "Evaluation of coconut based multi-species cropping systems for East Coast region of Tamil Nadu", Journal of the Andaman Science Association Vol. 19(1):59-64 (2014)

Hence in order to reduce the degree of production and price risks under coconut monocrop, farmers can adopt suitable coconut based cropping / farming system models.

Conclusion

There are possibilities of increasing the productivity and net returns from coconut gardens by raising compatible subsidiary crops and/or integrating with live stocks. The farming system models have conclusively proved that the scientifically designed coconut based farming system is not only capable of generating higher income, but also improving employment potentials of small-holders. In a scientifically laid out coconut based farming, unlike the traditional ones, the resource use efficiency gets considerably enhanced from crop inter actions in the system.

Since a large majority of the plantations are less than one hectare in extent, in developing the inter/mixed cropping system, the feasibility and economics including employment opportunities that may be generated and credit requirements for such intensive cropping systems as well as the size of the holdings should be carefully taken into account. During the initial establishment period, the investment on the intercrops alone becomes recoverable during the course of the year, as the response to inputs in coconut accrues only from the third year. This would mean that credit facilities are necessary for successful adoption of this intensive cropping programmes and realization of enhanced agricultural production.

The current sectoral innovation system of coconuts in India has huge strengths on the research front of coconut, but on the other hand lack of price stability, inadequate price support mechanism and marketing facilitation are the major factors detrimental to the efficient functioning of coconut value chain. Our past experience with the coconut value chain reinforces these factors wherein an active participatory support in all facet of the functioning of the chain is inevitable. The coconut industry will revive dramatically if it is made part of Prime Minister's 'Make in India' campaign. This can be made possible through formation of coconut parks across the major hubs, which can provide new impetus to the coconut industry by ensuring economic enhancement of the farmers and other stakeholders through large scale activities. The international norms stipulated for similar parks should be followed and the facilities of the park should be extended to entrepreneurs willing to set up coconut based value addition/processing units. As a proactive step to enter into the premium value export sector, establishment of quality control and testing lab in accordance to the sanitary and phytosanitary (SPS) regulations should be envisaged.

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