COCONUT INTERCROPPING SYSTEMS

Technical Report

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COCONUT INTERCROPPING SYSTEMS (CIS)
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(Unreferenced diagrams and photographs by Compton L. Paul)

1. Introduction
Production alternatives for intercropping in coconut plantations can take the form of a single intercrop, a mixture of crops, or a crop/livestock combination which are compatible with each other and other environmental factors. One of the most common farming systems practised by coconut growing traditional farmers is the coconut-based farming system (CBFS). This is a multiple cropping or crop/livestock production system aimed at maximising and/or complementing the benefits that can be derived from land under coconut (Ohler, 1992).
Mono-cropping coconuts provides very low incomes for farmers even with an optimum planting density. However, there is a large area of land beneath the canopy of coconut plantations available for the farmer to use (Fig. 1). Weeds growing beneath the palms compete for moisture and nutrients and decrease yields. 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 (Proud, 2005). But judicious selection of compatible intercrops, proper manuring and adoption of scientific intercrop management practices are absolutely essential for reaping handsome benefits out of it (Oommen, 2001).

Figure 1. Area of land beneath the canopy of coconut plantations available for intercropping.
The coconut intercropping system is based on the premise that the intercrop is beneficial to coconut production and productivity and that the income and efficiency of resource use including labour, land and input supplies from the integrated system is greater (Reynolds, 1988). Coconut farmers can increase their profitability while reducing financial risks by adopting an integrated farming system that includes animals or intercrops.

In coconut intercropping systems, the general rule is to plant the coconut component at the traditional spacing and utilise the understorey space for intercrops which are really an aid (especially in weed control and the provision of additional income) to the coconut enterprise which takes priority. The active root system of a coconut palm is concentrated only within 2 meters from its base. Therefore, for a coconut plantation with a spacing of 8m x 8m about 8,000 sq. metres space is left unproductive. To maximize the use of land and other resources such as manpower, machinery, fertiliser, pesticide, etc, intercropping is then adopted.

Another reason why intercropping is practised is the unusual fluctuations of the price of copra. Inclusion of other crops lessens the burden of the coconut farmer by giving alternative sources of income.

One general rule in intercropping is to arrange to rows of intercrop in a way that these receive maximum sunlight throughout the day. With regards to selection of crops, the following factors must be considered:

- Market for the intercrop -- coconut farmers must ensure they know where to sell the products of the intercrop.
- Competition the intercrop may offer to coconut as regards to sunlight, water and nutrient requirement. Intercrops must be selected so as not to compete with sunlight, water and nutrients. Coconut tree canopy must carefully be calculated so as not to over-shade the intercrop. In very tall coconut varieties, sunlight increases as the height of coconut trees becomes taller. Dwarf and hybrid types tend to have greater fronds and cause increased shading of the intercrop. In older plantations where trees are tall enough to allow more light penetration, intercrops that require less shading can be used.
- Irrigation and fertilisation of intercrops favour the coconut component and often increase its yield.
- Ecological factors.
  - Microbial activity – The intercrop can improve the microbial activity of the rhizosphere. It can also increase the soil organic matter by its crop residue left in the field. Nitrogen-fixing and phosphate solubilising bacterial activity can also be beneficial. All these factors can result in increased coconut yields.
  - Increase of pests and diseases - some intercrops favour the build-up of pest and disease populations unfavourable to the coconut plant. In other instances, however, build-up of parasites and predators can occur.
  - Pesticides used in the intercrops can be harmful to the coconut component.
2. Ecological considerations for maximum yields

Coconut palms can grow in various environments, although certain ecological conditions limit their growth. According to Darwis (1990), limiting ecological factors include rainfall, altitude, swamp area, and soils. Several agro-climatic factors thus affect productivity, including altitude, rainfall, temperature, relative humidity, wind, sun radiation, daylength and, soil type including its physical and chemical properties (Waney and Tujuwale, 2002).

Coconut requires suitable annual rainfall ranging from 1200 to 2500 mm/year (Darwis, 1990; De Taffin, 1998). Monthly rainfall also plays a key role in determining coconut growth and production. The mean annual temperature for optimum growth and maximum yield is stated to be 27°C with a diurnal variation of 6°C to 7°C and relative humidity at 80 - 90%. An average ambient temperature of 27°C is good (<20°C and >34°C not suitable). When the average monthly minimum temp is less than 18°C, growth is reduced and female flowers abort. However, some varieties may produce satisfactorily at temperatures less than 18°C. Optimum sunlight is 2000 - 2200 hours /annum with the minimum being 1500 hours/annum or 125 hours per month (Waney and Tujuwale, 2002).

Coconut does best in loose well-drained soils about 50 - 100 cm deep with good moisture-holding capacity. Production is limited by shallow and compacted soils, heavy clays, waterlogging and drought.

Altitude affects coconut production and oil content. The higher the elevation, the lower the temperature. Optimum altitudes are below 400m at latitudes between 20° and 30° north and south of the Equator but coconut plants can grow well up to an elevation of 900 m at this same latitude. Trees that grow at elevations above 500 meters produce a thin endosperm and low oil content (Waney and Tujuwale, 2002).

3. The coconut component

There are two recognised types of coconut variety, namely, dwarf and tall types. These are simply distinguished according to their height. Dwarf varieties are usually early maturing and produce nuts earlier in their life compared to the tall varieties. Tall varieties, however, yield more nuts than dwarf varieties (Agfishtech Portal, 2012).

Commercial cultivars can be sorted mainly into tall cultivars, dwarf cultivars and hybrid cultivars (hybrids between talls and dwarfs) (Fig. 2). Some of the dwarf cultivars such as Malayan Dwarf has shown some promising resistance to lethal yellowing while other cultivars such as Jamaican Tall is highly affected by the same plant disease. Some cultivars are more drought resistant such as West Coast Tall (India). Other aspects such as seed size, shape and weight and solid endosperm thickness are also important factors in the selection of new cultivars (Wikipedia, 2015).

Trees that produce more than100 nuts per tree per year are considered to be very productive. The most popular dwarf cultivars are the Malayan Green, Red and Yellow.
Hybrids of tall types such as Panama Tall and Jamaican Tall x Dwarf Malayan are popular (Pilgrim, 2011). Tall types come into bearing at 7-10 years of age and have a productive life span of 70 years while dwarf types take 1.5 to 3 years to come into bearing and have a productive life span of 30 years.

Figure 2. General types of coconut.

- **Nursery establishment and management**
  Sturdy planting material (seedlings at 6-9 months old or those with 6-8 firm healthy leaves) should be obtained from nurseries where dry mature nuts are selected from high-yielding healthy trees and propagated in seed beds or polybags. Early germination and good vigour of seedlings is important.

  (i) **Seed preparation** (De Taffin, 1998)
  Select healthy and uniform seeds. Store in heaps no higher than 1.5m. Store no more than 10 days for dwarf types and no more than 21 days for tall types.

  (ii) **Planting in the seedbed (pre-nursery)**
  Pare nuts at end where shoot emerges and sow 1/3 in soil of fine tilth. On non-rainy days, apply 0.5 liter water to each seedling every day. Each bed must consist of only one cultivar and all must be of same age. 80% germination acceptable. After about 4 months (sprout a few cm long) germinated nuts are selected for transplanting into nursery beds. Early germination is correlated with early yield. Selected sprouts should be single, sturdy, straight and well set into the husk. Plants with thin or spindly sprouts, 2 or 3 stems and leaves with
shortened lamina are discarded. Off-colour sprouts are discarded (since green colour of tall parent is dominant, yellow or red sprouts resulting from hybrid crosses of red or yellow dwarfs x talls should be discarded). A maximum of 12% discards is acceptable at this seedbed stage.

(iii) **Planting in the nursery proper**
Selected germinated nuts are lifted out of the seedbed and transferred to polybags for placement in nursery beds or placed directly into nursery soil of fine tilth. On non-rainy days, apply 1 liter to each seedling every 2 days and control weeds and insects. Space plants 60 x 60cm for 6 months stay in nursery; 80 x 80cm for 9 months stay; and, 100 x 100cm for 12 months stay. Apply fertiliser mixture (1 unit urea + 2 units TSP + 2 units KCl + 1 unit MgSO4) at 30 g/plant (1 month), 60g/plant (3 months), and 75g/plant at 5, 7 and 9 months.

(iv) **Transplanting to field plots**
At 6 to 8 months, dwarf x tall hybrid is 18 - 20cm circumference at collar and 110 – 120cm tall with 7 - 8 leaves and the youngest already differentiated into leaflets. Discards at this stage should not be more than 15%. Overall, 100 plantable seedlings for field plots should be obtained from about 172 nuts entering the nursery (about a 42% loss of nuts from nursery to field plots). An acaricide should be used to treat the seedlings against Red Palm Mite.

The seedling should be planted in a 60 - 90 cm deep hole 30cm x 60 cm. Organic material such as dry coconut husk should be placed at the bottom of the hole and covered with a 3:1 mixture of soil and pen manure. Approximately 100g of NPK fertilizer should be placed at the base of the seedling (Pilgrim, 2011). Thereafter, NPK fertiliser should be applied every 3 months for the first year at the respective rate of 0.5 kg, 1 kg, 1.5 kg, and 2 kg per plant. From the second year onwards, compound fertilisers high in potassium should be applied at the rate of 1 kg per plant every 6 months (Pilgrim, 2011).

- **Spacing and arrangement**
The most important management tool in achieving optimal overall system productivity is appropriate coconut spacing since this determines the amount of light that penetrates the canopy. The density of coconuts per hectare determines how much sunlight will get through to the understorey. The optimal spacing for good overall pasture and coconut production is reported to be 10 x 10 m on flat or gently rolling terrain and 9 x 9 m on slopes (Guzman and Allo, 1975; Opio, 1987). Compare this to the recommended spacing for maximum nut production alone on flat land which is 8 x 8 m. Nair (1979) estimates that even at this spacing, only 20% of the total soil area under the coconuts is effectively utilised by their roots. A general spacing of between 7.6m x 7.6m and 9.1m x 9.1m is recommended with a pineapple planting configuration. Dwarf types and hybrids are often planted at the
closer spacing since their larger and denser fronds cover the ground much more than tall types. Wider spacings also favour intercrops or pastures.

A triangular (Fig. 3) as opposed to square-spacing arrangement is now recommended by most experts because it allows for more coconuts, more canopy interlock/overlap, and thus more effective interception of sunlight at any given spacing. One would suspect, then, that a square arrangement is preferred where pasture production is an objective. With a square arrangement, more light reaches the understorey pasture. However, this extra light is concentrated through wide gaps in the canopy so that some spots in the pasture receive much more light than others. Because uniformity of growth and species mix is one goal of pasture management, the triangular arrangement is still be preferred here. Coconuts in this arrangement, shade the ground more uniformly.

**Figure 3.** Triangular spacing arrangement for coconut.

- **The age factor**
  A stand of coconuts casts varying degrees of shade depending upon its height and thus its age. In young plantations, plenty of light reaches the ground. Shading gradually increases until the palms are about 10 years old. Thereafter, understorey sunlight gradually increases to a maximum level when the palms are approximately 20 years old. It may be best to plant different crops in the understorey at these different coconut growth stages.

- **Crop nutrition**
  Coconut palms require adequate nutrition during the early years, prior to flowering, to promote vigorous growth, early bearing and high yields. The most rapid growth occurs between the second and fifth year in the life of the coconut palm. The soils on an old coconut plantation are expected to be impoverished if there was not a fertilizer programme in place. Planting new and improved palms to replace old coconut groves makes little sense if adequate nutrients are not supplied to the plants.
Nitrogen is important in promoting leaf growth and development. Deficiencies in phosphorus retard palm growth and delay flowering. In potassium deficient soils, potassium fertilizers have a positive effect on the number of inflorescences, bunches, nuts per bunch and total nut production. Ideally, fertiliser recommendations are based on soil tests and tissue analyses. The fertiliser recommendations (Ramkhelawan, 2013) per palm at different ages based in coconut growing areas in Trinidad and Tobago, along with the nutrients required to produce 100 nuts per year are shown in Table 1.

Table 1. Rate of Fertilizer application of 15-5-20 NPK/palm/year

<table>
<thead>
<tr>
<th>Age of palm</th>
<th>Application * (lb/tree/year)</th>
<th>Number of applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult &gt;4 years</td>
<td>5</td>
<td>2 (June &amp; December)</td>
</tr>
<tr>
<td>1 year and less</td>
<td>1/10th of adult dose</td>
<td>At planting &amp; 6 months later</td>
</tr>
<tr>
<td>2 years</td>
<td>1/3rd of adult dose</td>
<td>2 (June &amp; December)</td>
</tr>
<tr>
<td>3 years</td>
<td>2/3rd of adult dose</td>
<td>2 (June &amp; December)</td>
</tr>
</tbody>
</table>

* 1 kg = 2.2lb

The fertilizer should be broadcasted 1m to 2m from the trunk and 0.5m to 1.0 m for young palms. On sloping lands, the fertilizer should be incorporated to a depth of 15 cm at various points at the same radius described before. In addition to the recommendations shown in Table 1, where soils are acidic, 2kg of finely ground dolomite limestone should be applied per adult tree per year. Coconut husks are high in potassium. Burying fresh or dried husks 2m around the palm may reduce fertiliser cost through nutrient cycling. It can also increase retention of moisture and would benefit drought-prone areas. The application of fully decomposed farmyard manure, where available and economic, has also been found to be beneficial to the palms.

• **Irrigation**

Irrigation is necessary to provide sufficient water and mineral soil conditions and so result in good growth, development and yield. During periods of drought, there is high mortality of transplanted seedlings, shedding of young nuts, drying and hanging down of older fronds and young fronds fail to open. It is important that rainfall be well distributed throughout the year for optimum coconut production. Coconut responds well to dry season irrigation i.e. in the dry months, irrigation @ 40 litres per palm per week can increase the yield of nuts by as much as 50%. Where water is scarce, a drip irrigation system is recommended and can make more efficient use of water, labour and energy.

• **Weed management**

Heavy weed growth makes the collection of fallen nuts a difficult exercise. Control may be done by tractor-drawn brushcutters, hand-held brushcutters along with herbicides. Any self-sown seedlings should be removed.
4. **Suitability of coconuts for intercropping**

Four main characteristics (Reynolds, 1995) determine the suitability of the tall coconut varieties for intercropping (i.e. tall unbranched trees, with a terminal crown of leaves, growing to a height of 20–30 m, with a life span of 80–100 years):

i. The planting distance should be in the range 7 m × 7 m to 10 m × 10 m for tall cultivars, with an average planting density of around 130 – 180 palms ha⁻¹, and as close as 5.5 m × 5.5 m for dwarf palms giving planting densities as high as 400 palms ha⁻¹, depending on whether rectangular, square or triangular planting systems are used (Fig. 4). In coconut monoculture as little as 25 percent of the land may be effectively used. According to Magat (1990), whereas the potential (maximum) annual biological productivity of a cropping system under optimum conditions is of the order of 280.5 t ha⁻¹ of dry matter per year (770 kg per ha per day), for coconuts even at high nut yields of 100 nuts per tree and 200 nuts per tree, the annual productivity is only 18.70 t ha⁻¹ and 35.5 t ha⁻¹ of dry matter (or 6.6 and 12.6 percent respectively of the potential biological activity). Clearly coconut monocropping has a very low utilisation efficiency of agricultural land and even with varietal improvement is likely to remain so.

ii. The morphological features of the coconut which mean that coconut palms may occupy less than 30–40 percent of the available air space between canopy and ground during the major part of their life span.

iii. The nature of the canopy of fronds and the proportion of incoming solar radiation which reaches the ground. According to Liyanage (1985), Liyanage and Martin (1987) and Nair and Balakrishnan (1976), on average some 56% of solar radiation is available for intercrops, although this will vary with age of the coconut stand and planting density.

iv. The depth of the roots which are mostly in the 30 – 120 cm soil layer in a 2 m radius around the palm (Fig. 4) thus leaving some seventy to seventy five percent of the soil unutilised or underutilised.

The introduction of dwarf varieties and the closer spacing of hybrids and tall varieties may reduce possibilities for intercropping, but at present most of the world area of coconut palms is of the tall varieties at wide spacings and in future plantings the choice of spacing may be influenced by the decision to intercrop (FAO, 1993).

Thus by the very nature of the coconut tree there is a large area of land beneath the tree canopy which the farmer has to decide how to utilise. If he does nothing then weeds will grow beneath the palms. He may choose to try to keep the weeds at bay by a variety of means or he may decide to establish intercrops.
Payne (1976) suggested that the weeds be replaced by forage species whose growth could be controlled by grazing animals (FAO, 1993).

**Figure 4.** Schematic representation of horizontal root distribution of a multiple intercropping system with coconut (Nelliat *et al.*, 1974).

5. **The intercrop component**

The arrangement of the components depends on the nature of the intercrop (Liyanage *et al.*, 1986; AgFishTech Portal, 2012). Generally, a circular area of radius 2 m around the palm is left free of intercrops and the intercrops are grown in the interspaces of coconut rows according to the recommended planting system for the sole crop of the intercrop concerned. The following are the main intercropping arrangement patterns:

- **Sequential cropping** (two or more crops in single stand one after the other on the same plot during the same year).
- **Simultaneous cropping** (two or more intercrops grown at same time).
- **Row intercropping** - simultaneous growing of two or more crop species in a well-defined row arrangement.
- **Strip intercropping** - simultaneous growing of two or more crop species in a strip wide enough to allow independent cultivation, but at the same time, sufficiently narrow to induce crop interactions.
- **Relay intercropping** - planting one or two crops within an established cropping pattern wherein the final stage of the first crop coincides with the initial development of the other crops.
Multi-storey cropping, for instance, coconut + black pepper + cacao + pineapple are planted so that each crop produces canopies at different heights.

At the conventional coconut spacings of 7m x 7m to 10m x10 m, various trials with annuals and perennials have proven that CBFS is feasible. In Africa, Asia and the Pacific, where intercropping practices are common, various species of annuals have been grown, most of which have given up to 60% increases in their yields, as well as that of coconut, compared to the same grown area of monocrops (Creencia, 1978; Cuavas, 1975 and Opio, 1992). There are many common annuals and perennials recommended for coconut intercropping systems. Many are shade-loving (coffee, cocoa, papaya, pepper) or shade-tolerant or adapted to partial shade (avocado, citrus, soursop, pommecythere, WI cherry, carambola, mango). Table 2 shows some of the commonly grown crops with coconut.

Table 2: Crops commonly grown with coconut

<table>
<thead>
<tr>
<th>Crop</th>
<th>Scientific name</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CEREALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>Oryza sativa</td>
<td>India</td>
</tr>
<tr>
<td>Maize</td>
<td>Zea mays</td>
<td>Phillipines</td>
</tr>
<tr>
<td>2. PULSES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mung bean</td>
<td>Vigra radiata</td>
<td>India</td>
</tr>
<tr>
<td>Pigeon pea</td>
<td>Cajanus cajan</td>
<td>India</td>
</tr>
<tr>
<td>Corn pea</td>
<td>Vigra unguiculata</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>Soya bean</td>
<td>Glysine max</td>
<td>Phillipines</td>
</tr>
<tr>
<td>Ground nut</td>
<td>Arachis hypogiaea</td>
<td>Phillipines</td>
</tr>
<tr>
<td>3. ROOTCROPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>Manihot esculenta</td>
<td>India, Phillipines, Sri Lanka</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>Ipomoea batatas</td>
<td>India</td>
</tr>
<tr>
<td>Yam</td>
<td>Dioscorea spp</td>
<td>India</td>
</tr>
<tr>
<td>Taro</td>
<td>Colocasia spp</td>
<td>Phillipines</td>
</tr>
<tr>
<td>4. SPICES and CONDIMENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ginger</td>
<td>Zingiber officinale</td>
<td>India</td>
</tr>
<tr>
<td>Tumeric</td>
<td>Curcuma longa</td>
<td>India</td>
</tr>
<tr>
<td>Chillies</td>
<td>Capsicum annuum</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>5. TREE CROPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocoa</td>
<td>Theobroma cacao</td>
<td>India, Malaysia</td>
</tr>
<tr>
<td>Coffee</td>
<td>Coffee canephora</td>
<td>Phillipines</td>
</tr>
<tr>
<td>6. OTHER CROPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>Gossypium spp</td>
<td>India, Sri Lanka</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>Saccharum officinarum</td>
<td>Phillipines</td>
</tr>
</tbody>
</table>

Source: adapted from Plucknett, 1979
Evaluation of some perennial intercrops suggests that growing cocoa, coffee, pineapple and bananas has no adverse effect on coconut yields. In fact, perennial intercrops, such as cocoa, benefit coconut (Ohler, 1992). Annual species suitable for intercropping with coconut include beans, peas, ochra, sweet potato, cassava, ginger, pineapple, colocasia spp., watermelon, pumpkin, peppers, cauliflower, cucumber, sorrel, broccoli, and tomato.

Intercropping takes advantage of the nature of the coconut tree’s canopy of fronds, and its rooting system (Proud, 2005). On average, 56% of solar radiation reaches the ground, although this varies with the age of the coconut stand, its planting density, and its alignment. A rectangular system, aligned in a north east - west direction, allows more sunlight to reach the alleys between the rows of trees (Fig. 1). Over 80% of the active roots occur in the 25 – 60 cm soil layer in a 2 m radius around the palm, leaving 70 - 75% of the soil available for use by other crops.

Intercropping with perennial, short-term, or cover crops rarely adversely affects the yield or growth of the coconut crop. Practices such as weeding and fertilising the intercrops may also increase coconut yields. Fallen coconuts are easier to recover in a clean understorey.

With widely spaced coconuts, i.e. above 7.6 m, intercropping is possible irrespective of the age of the palms. However, closely spaced palms, aged 8-25 years, are generally not suitable for inter- and mixed cropping. Mature plantations over 25 years old allow sufficient light to enter the understorey making conditions suitable for underplanting. The intercrops are planted far enough away from the coconut trees so their roots do not overlap as shown in a coconut/banana/pineapple system in Figure 5. A staggered layout may be needed to maintain optimum spacings. The spacing of the palms determines the number of lines of intercrops.
Figure 5. Representation of intercropping system of pineapple + banana + coconut. Distances between crops are arranged so that roots do not overlap.

- **Management practices**
  
a) **Zero tillage**
  Zero tillage and heavy mulching should be practised when intercropping coconut plantations on steep slopes. On flatter areas, tillage operations such as ploughing and hoeing should not be done within 2 m of the base of the tree to avoid damaging the coconut root system lying close to the surface.

  b) **Mulching**
  Clean weeding and spraying with herbicide can result in yield increases from 10 – 47 nuts per palm per year, but should be restricted to slopes of 0 - 12%, to prevent erosion. On sloping land, reduce the coconut palms’ demand for soil moisture by regularly cutting down the weeds and shrubs and applying them, along with fallen coconut leaves, as mulch around the trees. Mulch the pineapple and fruit tree intercrops to reduce competition for scarce soil moisture.

- **Coconut + cocoa intercropping**
  Cocoa can be intercropped with coconut (Fig.6) after the latter reaches 25 years; the cocoa does not compete with coconut for soil resources (Magat and Secretaria, 2007). Nair (1977) reported that intercropping coconut with cocoa improved coconut yields by 95%. Cocoa is a self-mulching crop and has large leaves which it sheds periodically. The leaves provide good mulching material, conserve moisture and increase soil organic matter.
There is also enhanced microbial activity, such as nitrogen-fixing and phosphate-solubilizing processes along with IAA-production by *Aspergillus flavus* and *Aspergillus fumigatus* in the rhizosphere. Intercropping with cocoa is one of the most beneficial practices to coconut.

Separate fertilisation of the two crops is recommended. The cocoa is planted in 3m x 3m squares leaving a space of at least 2 m from the row of coconuts.

- **Coconut + corn intercropping**

Coconut and corn (Fig.7) are planted at the same time with the corn rows at least 2 m away from the base of the coconut trees and 6-9 rows of corn can be accommodated between the coconut rows.
- **Coconut + banana/plantain intercropping**

Banana and plantain (Plate 1.) can be intercropped with coconut as soon as the coconut reaches 1 - 3 years of age; generally, the two crops do not compete markedly for soil nutrients (Magat, 1990).

With a spacing of 2.5 x 2.5 x 5 m in between two rows of coconut palms 720 banana trees can be accommodated in one hectare. Nutrient supply and irrigation management of the banana/plantain should be taken care of separately from the coconut for better yields. Fertilisation of 240 g urea, 220 g single super phosphate, 260 g muriate of potash and 10 kg of farm yard manure should be applied to the banana/plantain intercrop. The entire quantity of superphosphate may be applied on the 3rd month and urea and muriate of potash applied in two splits on 3rd and 5th months after planting. In India, it was found that in addition to the yield of intercrops the yield of coconut itself increased by 30 nuts/palm/year (Athmanathan et al, 2000).

![Plate 1. Coconut intercropped with banana (banana under tall coconut at left and under dwarf type at right).](image)

- **Coconut mult-storey cropping**

Nelliat et al. (1974) reported that the basic principle related to multi-storey cropping systems is crop compatibility, combining different crop heights and rooting systems. Although multi-storey cropping is one of the most effective land-use intensification systems that can increase the productivity of coconut land, its labour demand is high. Multi-storey cropping systems require more management skills, labour and other inputs than most systems (Ohler, 1992).

In a coconut, pineapple, papaya, peanut system (Fig.8), land is prepared for pineapple planting (30 cm x 100 cm or closer) along rows of coconut. Papaya seedlings are next planted at 3m x 3m with two rows in between rows of coconuts. During the first year, the annual legume peanut may be planted in between rows of papaya (6 rows of peanut at 50 cm apart). Papaya is harvested a year after, until the third year. On the second year, pineapple can be harvested and allowed to ratoon until the third year. Coconut harvesting for fresh nuts is done 9 months after flowering (at an interval of 45 – 60 days) and for dry nuts 12 months after flowering.
Figure 8. Field arrangement of mixed cropping model for coconut + pineapple + papaya + peanut cropping system.

- **Coconut + root crop intercropping**

  Popular root crops are cassava, sweet potato, ginger, eddo and dasheen and these can be planted as soon as the coconut is planted (Fig. 9). They are especially attractive as coconut intercrops in view of their shade tolerant nature. Recommended spacing is 0.75m – 1m rows with at least 2m of space from the coconut row. The interrow spacing for the intercrop depends on the particular root crop used and varies from 0.25m to 0.75m. These intercrops require adequate manuring to compensate for their high level of soil nutrient removal (Oommen, 2001); they are also not drought-tolerant.
• **Coconut + coffee intercropping**

The shade from the coconut trees provide optimum conditions for coffee tree growth and productivity. Coffee is planted 2m away from the coconut trees in 3 rows at 3m x 3m in a triangular arrangement while the coconut is planted in a 8 -10 m x 8-10 m square planting pattern. The coffee can be planted simultaneously with the coconut (Fig. 10).
6. Crop care of intercrops

Care of the intercrops must address their specific requirements of varieties and availability of planting material, land preparation, cultivation practices, resource inputs including agrochemicals, fertilisation, weed control, irrigation, drainage, pest/disease control, field sanitation, harvesting, transport, grading and, packaging.

Interaction of components in intercropping combinations is affected by light, water, nutrients, pest/host relationship, falling dry nuts damaging intercrops, cultivation of intercrops damaging the root system of coconut and other factors.

One general rule in intercropping is to arrange the rows of intercrop in a way that these receive maximum sunlight throughout the day. With regards to selection of crops, the following factors must be considered (Agfishtech Portal, 2012):

1. Market for the intercrop - coconut farmers must ensure they know where to sell the products of the intercrop.
2. Intercrops must be selected so as not to compete with the coconut for sunlight, water and nutrients. Tree and root canopy must be carefully calculated so as not to cover the intercrop. In very tall coconut, sunlight increases as the height of coconut trees becomes taller.

Carandang (1977) concluded that there is a need to select shade-tolerant crops for intercropping. However, of more significant importance is the increase in nut yields when coconut is intercropped. Carcallas and Aparra (1983) found that there was a significant increase in nut yields when palms were intercropped, ring weeded and fertilised. Increased nut yields are believed to be attributed mainly to fertilisation and inter-row cultivation. However, leguminous annuals could contribute to increased nut yields through their nitrogen fixation in the roots.

Since profitability of intercrops depends on yield levels and cost of production, net returns from intercrops may be increased if yields are increased and the overall production costs are minimised (Ohler, 1992).

7. Socio-economic aspects of production

The following factors must be taken into account:
- Financing
- Information systems
- Plantation infrastructure (machinery and equipment, irrigation and drainage system, access roads)
- Labour availability and cost compared to coconut monoculture
- Marketing system, cost of production, net income
- Environmental impact (agrochemicals effect on different species)

8. System constraints
The following can place constraints on the intercropping system:
drought, flooding, lack of financing, lack of technical know-how and information on coconut intercropping systems, price instability, cost and availability of labour, lack of appropriate intercropping species, planting material, transportation, pests, diseases and marketing.

9. Disadvantages of intercropping
The major disadvantages include the following (Reynolds, 1995):
i. Competition between intercrops and coconut, for water or plant nutrients.
ii. Intercrops may be uneconomical (losses to farmer) when planted where light is insufficient because coconut trees are too close together.
iii. Intercrops may harbour diseases or attract pests harmful to coconuts.
iv. Raising more than one crop on the same land area could increase the need for fertiliser, which may not be available.
v. Initially, as palms are shallow-rooted, tillage and cultivation operations required for intercrops may cause root damage to the main crop reducing yields.
vi. The growth habit of some intercrops may cause difficulty in certain coconut management operations (e.g. fertiliser application, harvesting).
vii. Intercropping may demand a higher level of skill from the farmer.
viii. Under smallholder production systems the supply of family labour is often limited and great pressure can be exerted on the household to allocate labour to the production of food crops and other more profitable cash enterprises at the expense of coconut production (Ohler, 1992).

10. Potential benefits of intercropping
The potential benefits include (Reynolds, 1995; Dalla Rosa, 1993):
i. Reduced market and financial risks, weed control, increased soil fertility, and increased coconut yield.
ii. Intercropping with perennials is popular on large-scale plantations. Perennials are particularly suited to intercropping with coconut because once they reach maturity they continue to provide a steady flow of income with little maintenance requirements.
iii. Increased coconut yields from fertiliser and irrigation applied to intercrops and increased food production.
iv. Increased stability for coconut farms through diversification and reduced dependence upon products with unstable market prices such as, copra, coconut oil, coir and others.
v. Care and attention given to management of intercrop tillage, weed control, use of fertilisers, among others, may lead to improved growth and yields of coconut and ease
in finding the fallen nuts. Coconut yields may receive more of a boost resulting from clearing undergrowth from existing areas than by planting large areas of new trees.

vi. As management of the ground under coconuts is necessary, income-producing crops are preferable to weeds.

vii. Reduced use of weedicides.

viii. Young palms require six or seven years to produce economic yields. Using cash crops, intercropped between the young coconuts, for food or sale, may help to offset the cost of coconut establishment and reduce the time to full bearing through improved palm growth.

ix. There may be better utilisation of underemployed labour throughout the year and the coconut farmer's skill level may be raised.

x. Possible reduction of the effect of natural calamities such as hurricanes, pests and diseases on total production since these do not usually affect all kinds of crops to the same extent or at the same time.

xi. Helpful in conserving foreign exchange by supplying the domestic market with essential food products thus reducing the need to import.

xii. Increased and diversified farm income and greater employment.

xiii. Better use of scarce land resources.

xiv. Coconut canopies may result not only in lower air temperatures (beneath the canopy) but also in lower soil temperatures which may be important for better seedling survival, soil water relations and possibly rate of litter breakdown and nitrogen mineralisation. Also, air relative humidity will be higher and soil water availability for intercrops will be maintained at a higher level than in the open because of less evaporation from the soil and lower crop transpiration rates.

xv. Many by-products from tree crop processing are readily available and potentially valuable for ruminant feeding and strategic supplementation.

11. Institutional support

This is required in areas of policy, credit, subsidies, incentives, industry strategy, land availability and tenure, farmer associations’ formation and strengthening, marketing and import/export facilitation for coconut and intercrop products, technical assistance, extension service and, training. In the Caribbean, research and development thrusts are necessary for coconut intercropping, product standards, food safety and, environmental impact.

12. Concluding remarks

The acceptability of any intercropping programme will depend upon the farmer’s own judgment and evaluation of the practice. Decisions will have to be taken as to whether there a need to increase coconut plant spacing (adjust plant density) to better accommodate coconut intercropping systems in new plantations. The answer lies in the income generated from the integrated intercropping system and the management inputs required. Careful analysis will have to be done on comparative coconut yields, constraints, benefits and profit margins. The logistics of multiple cropping have to
include schemes to ensure that the necessary inputs are available to the farmers in the right form and at the right time. Farmers should have the means to purchase these inputs and there should be a reliable and approachable market at the end of the season, at a price sufficient to ensure a reasonable profit and an adequate incentive to continue.

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