# Opportunities for Organic Cultivation of Coconut Palms

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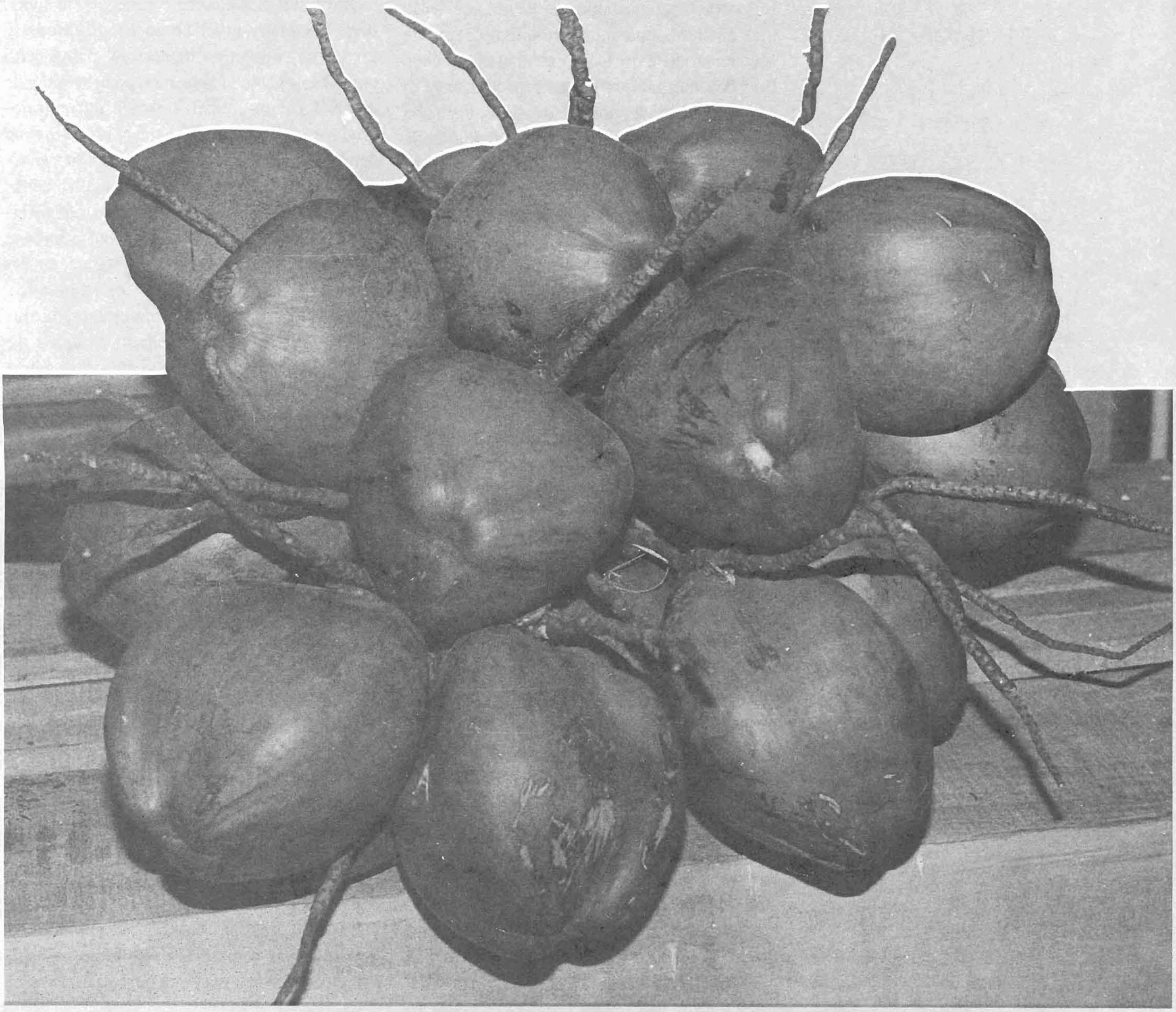
## Introduction

India is one of the largest coconut producing countries in the world. Coconut contributes 6 percent to the national vegetable oil pool and about 10 million families depend on it for their livelihood. Most of the production comes from small and marginal holdings. More than 90 percent of holdings are below one hectare with an average of 0.22 hectare. Despite the potential for impressive high yields, the national average is only 40 nuts/palm/ year, which is only half of what is realized in experimental fields under rainfed conditions. A number of high production technologies suitable for coconut are available and there is evidence that nutrients and moisture supply regulate coconut productivity to the extent of 80 per cent. But, coconut palm is grown predominantly in acidic and nutrient poor laterite, sandy loam and coastal sandy soils deficient in at least one macronutrient or the other. From the limited volume of these impoverished soils, tall cultivars planted in one hectare export about 56 kg N, 12 kg P, 70 kg K, 34 kg Ca and 12.5 kg Mg per year from the system. As coconut palm is perennial with continuous flowering habit, it is clear that unless these nutrients are replaced continuously, it will seriously affect the productivity.

There is evidence that chemical fertilizers can increase coconut yields. But unfortunately, due to high cost, only limited number of farmers use chemical fertilizers and even among them, a very few apply the recommended dose, leaving a vast majority of palms underfertilized and unfertilized. Increasing the area under chemical fertilizer use may not be the answer to the problem. Fertilizers, especially nitrogenous one are getting costlier every year and emphasis now has to be on low cost production technologies that can enhance yields, enabling competition in the international markets. The continuous use of chemical fertilizers have a number of long-term adverse effects on physical and biological properties of soil. This is much relevant today, as the importance of maintaining and improving soil quality for sustaining crop productivity is now well recognized. Large scale use of high analysis fertilizers are known to mediate a number of environmental hazards such as eutrophication, enhanced nitrate content in drinking water etc. Continuous use of chemical fertilizers can also result in soil acidity, imbalances in soil nutrient levels and decrease in availability of micronutrients. Already, boron deficiency has become a very serious problem in many coconut-growing tracts. Even if efforts are made to use chemical fertilizers in all coconut plantations, it would be difficult to bridge the gap between the present use of 36 kg NPK/ha to the recommended use of 353 kg NPK/ha. This calls for attention towards other cheap sources of nutrients to meet the crop needs, which at the same time help in maintaining and improving native soil fertility and productivity. In addition to this basic requirement of sustaining coconut productivity, there are many other compelling reasons in favour of cultivation of coconut palms with organics. There is ever increasing worldwide demand for organically grown agricultural produce and products. There is also growing demand for organic coconut products and spices (which are usually grown in coconut plantations as mixed crops), in the western world. This trend is likely to continue and spread to India in future and farmers who produce organic tender nuts and mature nuts may get a premium price. Considering this growing importance, in this paper efforts have been made to condense the basics of organic farming, the issue of sustaining coconut yields through organic farming and to review the work on agrotechniques suitable for organic cultivation of coconut.

### Soil Management for Sustaining Coconut Productivity

Whatever impressive may be the genetic potential of coconut palms, satisfactory yield can be expected only if they are cultivated in a suitable environment with proper management practices. Soil forms the basic natural resource, which during the whole life cycle of the palm determines the availability of nutrients and water, the most important inputs which decide the nut yield to a very great extent. As coconut palms are committed to soils for many decades, unless the quality of soils is maintained and regularly improved, it is very clear that the yield levels cannot be maintained and improved. In the wake of increased concern about the deteriorating natural resource base and declining yields in agriculture sector as a whole, more importance is being given nowadays to these aspects in coconut cultivation by scientists and farmers alike. Nutrient depletion in neglected plantations and excessive or unbalanced chemical fertilizer application in plantations managed through modern agrotechnologies result in one or many soil-related problems and in long run, soil productivity comes down very much. Yield reduction is preceded by decline in soil organic matter content, water storage capacity, loss of physical properties and number and activity of soil flora and fauna. Any system of soil and crop management adopted should be evaluated based on its capacity to maintain/ improve physical, chemical and biological properties of soil. Such soil management systems capable of protecting soil from degradation may be called *sustainable*. To sustain means to maintain a proper level or standard. According to the Technical Advisory Committee of the Consultative Group on International Agricultural Research (TAC/ CGIAR, 1988) *"Sustainable agriculture is the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources"*. In short, sustainable agriculture has twin objectives of increasing production and enhancing the quality of natural resource base. Sustainability requires that no non-renewable resource be used as an input and if used, it must be fully recycled. As far as possible, all the resources used in the system should be generated internally. Use of organic wastes and biological nutrient cycling methods are recommended for sustaining soil productivity as all these derive energy from sun light which is a renewable resource. Fertilizers which are basically petroleum originated products are to be avoided to the extent possible and when used, it should be ensured that they are used with maximum efficiency. The system of soil management adopted should ensure continuous recycling of



nutrients, preservation of soil organic matter, prevention of loss of nutrients and finally, recovery of the lost nutrients. Such a system which integrates the objectives of production and ecology will reduce the dependence of farmers on external inputs. These man-made agroecosystems will have resemblance to natural ecosystems and some elements of self regulation as seen in natural ecosystems can be visible in these also. A conventional agroecosystem differs from the natural one in this aspect that nutrients are constantly being removed from the conventional system. In natural ecosystems, there is self regulation in the functioning and nutrients taken up are recycled continuously through crop/ animal residues by the activity of soil flora and fauna and nutrient cycles are almost closed ones. By designing farming systems that mimic Nature, optimal use of all the natural resources such as soil, sun light, water and air can be made and nutrient flows can be converted into nutrient cycles. This leads to optimal yield, in addition to leave the natural resource base unaltered. With the objective of sustaining yields, a number of concepts, principles and agrotechnologies have been developed for adoption by farmers, and all of them have the common theme of recycling of nutrients in the system.

## The Concept of *Living Soil* and the Basic Principles of Organic Farming

Soil is now recognised not as an inert material, but a medium supporting the growth of a large diversity of macro and micro flora and fauna. Soil harbors a variety of insects, earthworms, enchytraeids, nematodes, fungi, actinomycetes, bacteria and hosts other known and unknown organisms, which together support plant life through a variety of physical and biochemical activities. Historically much attention was focussed on impacts of agriculture on soil erosion and depletion of soil organic matter. But, more recently attention has been focussed on studies of long term impact of agriculture on biological and biochemical parameters of soil. The activity and numbers of soil flora and fauna are increasingly considered as true indicators of soil quality or soil health. Biologically mediated processes are central to the ecological functioning of soil and soil biological activity is the driving force in the decomposition of organic matter, formation of humus, nutrient transformations, evolution and maintenance of stable soil structure, biological fixation and solubilisation of nutrients and biological control of soil-borne diseases. Only those soils with high diversity of flora and fauna can continuously support the growth of healthy crops and are termed *living soils* and are considered as the basis of organic farming. For normal functioning of soils, these organisms should be given proper conditions for multiplication, growth and activity. For this, all organisms need continuous supply of organic wastes as a source of energy and nutrients. Most of the conventionally cultivated soils are not able to derive benefits from these organisms due to the lack of sufficient reserve of organic matter, toxicity due to anthropogenic chemicals, lack of soil moisture and changes in an array of edaphic environment brought about by cultivation. Because of all these reasons, under normal conditions , most of the organisms will be in a state of inactivity. This paradoxical condition occurring in soil is commonly referred to as *sleeping beauty paradox*. By ensuring a proper supply of organic matter, the inactive organisms can be put back to activity and soil can derive nutritional and physical benefits due to their activity. The basic principle of organic farming is that if soil is fed properly with organic wastes, it will in turn ensure good nutrition for plants. By supplying soil with required amount of organic wastes, Nature can be encouraged to build up soil biodiversity and thus develop its own capabilities and mechanisms to support plant growth by supplying nutrients and preventing nutrient loss etc. By following organic farming technologies, we can ensure availability of enough organic wastes for recycling, create favourable conditions for their early decomposition, and favour the growth and activity in an array of soil flora and fauna.

## Organic Farming and Its Relevance in Coconut Cultivation

Coconut palms export nutrients to the above ground level parts continuously from a limited volume of soil throughout its existence. Unlike other field crops, there is no critical stage for nutrient requirement of coconut palm. Since the palms produce a spadix in the axil of each leaf, the yield depends on the number of leaves produced per year. Vegetative as well as reproductive growth goes on simultaneously and nutrition is important throughout the growth. Any deficiency of nutrients at any stage will affect vegetative growth and will directly reflect on yield. It is therefore essential that a nutritionally rich environment is provided in the root zone of coconut throughout the year to realise adequate yield. It has been found that coconut palms remove annually 56 kg N, 12 kg P, 70 kg K, 34 kg Ca and 12.5 kg Mg from one hectare . Among these nutrients, potassium and nitrogen are the most important and should be replaced continuously to maintain yield. Straight fertilizers can supply mainly primary nutrients and their continuous use will have adverse effects on physical, chemical and biological properties of soil. Again, as chemical fertilizers are applied during monsoon seasons, nutrient use efficiency from chemical fertilizers will be very low, leading to environmental problems. On the other hand, nutrients held in organic manures become available to the plants slowly over many cropping seasons as a result of the natural control over mineralization. Nutrient use efficiency will be high in this case due to conservation of nutrients by microbial immobilization. In addition to this nutrient supplementation role, organics have many complementary roles in coconut production. Organic substances by themselves are not necessary for palms to grow, on the other hand nutrients in inorganic form are sufficient. However, the effect of organic matter on the growth of palms is not a matter of nutrient supply. Organic materials influence the physical, chemical and biological characteristics of soil, which in turn influence growth, development and health of plants as described earlier. Organic materials have been found to benefit coconut palms in healthy and diseased periods alike. Use of *Gliricidia* green manure has been found to reduce the incidence of burrowing nematodes. Similarly, use of organic materials can reduce the disease index in root wilt affected palms and will enable farmers to harvest at least some yield. Even in cases where chemical fertilizers are used, use of organic materials will enhance the nutrient use efficiency of the palms.

## Coconut: A Crop Highly Amenable for Organic Farming

The growth habit and planting methods of coconut make it highly suitable for managing through organic farming. Perennial plants in general produce huge amounts of organic wastes throughout the year. The planting methods of coconut palm also make it possible to accommodate a number of intercrops which in return add lots of organic wastes to the system and recycling of these wastes within the system make it productive even in the absence of external inputs . Again, coconut palm wastes are rich in lignin, which in due course get converted into humus. Humus is a complex aggregate of brown/ dark coloured amorphous substance that gives soil its unique characteristics. Even though lignin-rich coconut palm wastes will take comparatively more time for decomposition, once they get converted into humus it can influence soil properties for a long period. Similarly, polyphenols present in coconut palm wastes in large amounts have the capacity to reduce nitrification process and thus they can reduce the loss of nitrogen from the system.

| Table-1: Nutrients recycling per year from the by-products in mixed farming | | | |
|---|---|---|---|
| By-products/year | N (kg) | P (kg) | K (kg) |
| FYM-15 tonnes | 75 | 40 | 75 |
| Poultry manure-2 tonnes | 20 | 38 | 12 |
| Cows' urine and cowshed washing – 50000 liters | 30 | - | 28 |
| **Total** | **125** | **78** | **115** |

*Source : Maheshwarappa et al., 1998*

From a well-managed coconut garden dry material of about 14-16 t/ha/year becomes available in the form of leaves, spathe, bunch waste and husk. It has been estimated that from coconut plantations in India, a total of about 14.36 million tonnes of organic materials, including coir pith are available for recycling. If fully recycled, these wastes can meet a major portion of nitrogen and a part of other nutrient needs of coconut plantations. The use of these wastes as domestic fuel and thatching material is decreasing in recent years and now there is scope for recycling of these wastes into most of the nutrients within the farms. Huge quantities of organic materials also become available from intercrops commonly grown in coconut garden. It has been observed that 818 and 1785 kg/ha/ year dry cocoa litter become available from single and double hedge systems of planting respectively. Similarly, green manure cover crops such as *Mimosa invisa, Calapogonium* and *Pueraria* can be grown in coconut basins and it can provide 15-20 kg green manure/basin. This can meet about 50% of nitrogen requirement, in addition to improving organic matter content of the soil.

### Agrotechnologies for Coconut Cultivation Based on the Basic Principles of Organic Farming

Soil productivity as well as coconut yield can be improved to a very great extent by applying the basic principles of organic farming for designing and developing low cost technologies based on the local resources. These agrotechnologies integrate ecological principles into intensification process and ensure that plant nutrients are in constant and close cycling within the soil and plant compartments are with minimal losses from the system. They rely on a wide variety of biological strategies adopted by soil systems for recycling nutrients and are based on the fact that functioning of ecosystem is governed by soil microbial dynamics. Technologies are available for production of sufficient quantities of organic matter for recycling, production of high quality composts, conservation of soil organic matter, prevention of loss of nutrients, recovery of lost nutrients etc. Enhancement of biodiversity is the primary principle used to evoke self-regulation and sustainability in agroecosystems. When biodiversity is restored, a number of complex interactions between soil, soil organisms, plants and animals are established, giving stability to the system. Many farming / cropping systems with a number of components mimicking nature have been found to work well and enhance coconut yield.

### Systems Approach for Sustaining Soil Productivity

Farming/ cropping systems designed based on local resources and needs, consider the whole farm as a single unit and all components are given importance in the functioning of the system. These systems mimic nature and create conditions and microclimate suitable for the multiplication and activity of a variety of beneficial organisms. They protect soils from direct sunlight and rainfall and thus preserve soil organic matter reserves. As a number of component crops are involved soil resources

| Table 2 : Biomass and nitrogen contribution of green manure legumes in coconut basins | | | | | |
|---|---|---|---|---|---|
| Sl.No | Legume species | Laterite soil | | Sandy soil | |
| | | Biomass kg/basin | Nitrogen g/basin | Biomass kg/basin | Nitrogen g/basin |
| 1 | *Calapogonium mucunoides* | 27.21 | 186.53 | 14.71 | 102.61 |
| 2 | *Mimosa invisa* | 24.97 | 197.55 | 17.00 | 153.19 |
| 3 | *Pueraria phaseoloides* | 28.45 | 196.19 | 19.43 | 121.29 |

| Table 3: Effect of basin management with green manure legumes on root (wilt) disease and yield of coconut palms | | | | |
|---|---|---|---|---|
| Treatment | Root (wilt) index | | Nut yield/palm/yr | |
| | Pre-treatment | Post-treatment | Pre-treatment | Post-treatment |
| *M.invisa* | 18.00 | 17.91 | 2.32 | 54.46 |
| *P.phaseoloides* | 12.38 | 16.58 | 39.51 | 63.84 |
| *C.mucunoides* | 21.12 | 20.91 | 42.96 | 52.21 |
| *Control* | 19.38 | 24.18 | 26.50 | 38.93 |

are utilized to the maximum extent and thus preventing the loss of nutrients from the system. As the biomass production per unit area will be very high, soil health and coconut yields can be sustained even in the absence of external inputs when the available organic wastes are recycled. These systems can be adopted even by small scale farmers and the coconut based homestead farming in Kerala is a typical example for this.

High density multispecies cropping systems (HDMSCS) involve growing a large number of crops at very high plant population per unit area to meet the diverse needs of the farmers. They are ideally suited for smaller units and aim at maximum production per unit area of land with minimum time and inputs or no deterioration of land. From the model (coconut, clove, banana and pineapple) developed at Kasaragod , 11.6 to 16.46t/ha/year biomass get available for recycling from coconut cultivated under graded fertilizer doses. The annual nutrient export by the crop per hectare ranged from 92.37 to 149.31 kg N, 12.94 to 20.79 kg P and 119.09 to 183.62 kg K. The extent of nutrient recycling from the available biomass ranged from 45.99 to 81.88 kg N, 5.36 to 10.63 kg P and 79.39 to 127.34 kg K. This shows that a substantial saving in terms of fertilizer input can be achieved through effective recycling of huge quantity of the waste biomass generated by the system.

In an on going experiment on coconut based mixed farming of 1.2 ha involving coconut, grasses, dairy, poultry and rabbitry, 15 tonnes of farm yard manure and 2 tonnes of poultry manure and 50,000 liters of cow urine and cowshed washings are obtained annually. If effectively recycled these can supply 125 kg N, 78 kg $P_2O_5$ and 115 kg $K_2O$. (Table-1). There was build up of organic carbon, N, P, K and Fe status in soil. Leaf nutrient status of coconut palms was also increased resulting in increased nut yield. As fertilizers are the costliest inputs in coconut farming, through this system a lot of savings can be made in cultivation cost.

### Leguminous Green Manure Plants for Sustaining Coconut Yields

Leguminous green manure plants, either seasonal or perennial types can add a lot of green matter rich in nitrogen to soil in shortest time because of their ability to associate with atmospheric nitrogen fixing *Rhizobium* spp. This nitrogen-rich green matter will decompose easily and release the bound nutrients fast. Growth of legumes also increases the availability of phosphates. Because of their deep tap root system, they absorb nutrients that have leached down beyond the root zone of coconut palms and make available them to the palm when the biomass is incorporated into soil. Leguminous cover crops grown in coconut plantations during rainy seasons protect the soil from direct impact of heavy rains and serve as catch crops. Incorporation of legume biomass has also been found to enhance soil microbial population , population of VA mycorrhizal fungi, soil enzyme activity and carbon mineralization.

Legume cover crops grown in basins can generate about 15-20 kg green biomass per basin and legumes such as *Crotalaria* spp. grown in

**Table 4: Effect of application of different organic sources along with inorganic sources on soil physical properties**

| Sl No | Treatment | Hydraulic conductivity (cm/hr) | Water holding capacity (%) | Bulk density (g/cc) |
|---|---|---|---|---|
| 1 | Coir Dust + NPK | 181 | 33.80 | 1.37 |
| 2 | Coconut Sheddings+ NPK | 195 | 27.10 | 1.49 |
| 3 | Forest Leaves+ NPK | 176 | 27.20 | 1.50 |
| 4 | Cattle Manure+ NPK | 151 | 26.50 | 1.56 |
| 5 | Control (NPK alone) | 133 | 23.40 | 1.60 |

**Table 5 Influence of organic manuring on the nutrient contents of soil**

| Nutrients/Treatments | Coir dust +NPK | Coconut shedding +NPK | Forest leaves +NPK | Cattle manure +NPK | NPK alone (Control) |
|---|---|---|---|---|---|
| Organic carbon (%) | 0.170 | 0.143 | 0.159 | 0.173 | 0.06 |
| Av. N (ppm) | 43.6 | 48.6 | 50.3 | 50.6 | 27.0 |
| Exch.Ca (ppm) | 94.7 | 88.7 | 127.3 | 106.3 | 62.1 |
| Exch.Mg. (ppm) | 8.32 | 7.34 | 10.0 | 11.2 | 5.68 |
| Av. Mn (ppm) | 71.9 | 38.6 | 47.4 | 62.3 | 18.4 |
| Av. Fe (ppm) | 1.97 | 4.05 | 4.64 | 7.52 | 1.9 |

*Source: Nambiar et al., 1978*

**Table 6: Effect of pruning regimes and planting density on biomass yield of Gliricidia (Kg/ha)**

| Treatment | Fresh leaf matter | Dry matter | N | P | K |
|---|---|---|---|---|---|
| T1: coconut monocrop | - | - | - | - | - |
| T2: 2 rows, 3 prunings | 6194 | 1816 | 61.5 | 4.6 | 20.4 |
| T3: 2 rows, 4 prunings | 5479 | 1594 | 54.8 | 4.0 | 18.4 |
| T4: 3 rows, 3 prunings | 7970 | 2296 | 77.6 | 5.7 | 26.8 |
| T5: 3 rows, 4 prunings | 7211 | 2051 | 69.5 | 5.1 | 24.0 |

**Table 7. Coconut growth characters under coconut-Gliricidia alley cropping system (1998)**

| Treatment | Height (cm) | Girth (cm) | Total no. of leaves | Annual leaf production |
|---|---|---|---|---|
| T1: Coconut monocrop | 484 | 110 | 27 | 7.4 |
| T2: 2 rows, 3 prunings | 581 | 115 | 30 | 8.1 |
| T3:2 rows, 4 prunings | 526 | 106 | 28 | 7.9 |
| T4:3 rows, 3 prunings | 560 | 108 | 29 | 8.3 |
| T5:3 rows, 4 prunings | 546 | 113 | 31 | 8.8 |

interspaces can generate 3-4 tonnes of green matter per hectare. The perennial leguminous green manure plant *Gliricidia* is very fast growing, hardy and resistant to regular harvesting of green matter. This plant can be very well grown along the borders of coconut plantation and can generate huge amounts of nitrogen rich green matter.

### Basin Management with Legume Cover Crops

An agrotechnique has been developed to generate significant quantities of organic manure and nitrogen in coconut garden utilizing the leguminous cover crops. It involves cultivation of leguminous creepers having symbiotic association with efficient *Rhizobium* strains, in coconut basins and interspaces during the monsoon period and harvest and incorporate biomass generated at the maximum vegetative growth of legumes. A field experiment on basin management with two legumes in adult coconut plantations revealed the effectiveness of this technique to substitute fertilizer nitrogen for coconut upto 50 per cent. Coconut palms under the treatment of *M. invisa* and *C. mucunoides* exhibited higher yield than the palms which received the full dose of fertilizer nitrogen .The effectiveness of the legume treatment as a component in the management programme for root (wilt) disease of coconut has also been demonstrated in a field experiment in the root (wilt) affected areas(Table 2). Among the ten species of legumes screened, *Pueraria phaseoloides*, *Mimosa invisa* and *Calapogonium mucunoides* were superior in biomass generation and nitrogen contribution in coconut basins. They contributed 15-25 kg of biomass and 100-200 g of nitrogen in coconut basins during a growth period of 140-150 days in monsoon season (Table 3).

*P.Phaseoloides* and *M. invisa* were well nodulated by native rhizobia present in acidic coconut soils as indicated by nodulation characteristics and nitrogen fixing activity. If the native nodulation is poor or ineffective in a particular location, inoculation with biofertilizers of efficient strains of *Rhizobium* is necessary to obtain sufficient biomass and nitrogen yield. Pelleting of inoculated seeds with neutral or inert materials enhances nodulation by introduced rhizobia in acidic soils.

Basin management with legumes is an easily adaptable and less expensive agrotechnique for supplying organic manure and nitrogen at the site itself. It can form an important component in the organic farming technology of coconut for sustainable agriculture.

### Coastal Sandy Soil Management through Organic Farming

Organic manures apart from supplying plant nutrients, also have a profound impact on moisture retention, root growth and nutrient conservation. When organic manures are applied to coarse textured soils, there is a decrease in the bulk density due to better aggregation properties. Studies conducted at CPCRI, Kasaragod, have demonstrated that all the organic sources viz. forest leaves, coconut sheddings, cattle manure and coir pith in conjunction with inorganics significantly improved the soil physical characters over control (inorganic) treatment in littoral sandy soil (Table 4). The incorporation of organic sources blended with inorganic nutrients continuously for 10 years was found to increase the water holding capacity and decrease the bulk density of the soil as compared to the application of inorganic alone. The available soil moisture of 0.78% for plots treated with NPK alone increased to 1.94, 0.87, 1.39 and 1.13% respectively when coir dust, coconut shedding, forest leaves and cattle manure were incorporated along with NPK. There were significant differences between the treatment means in the case of organic carbon, available N, Fe, Mn and exchangeable Ca and Mg. The absolute values were very low for the soils receiving NPK alone, compared to those receiving organic manures (Table 5). Organic manures have also been found to enhance the growth and flowering of coconut seedlings. The establishment of coconut seedlings was better achieved in littoral sandy soils with organic amendments than NPK alone, suggesting that some of the usufructs of coconut also contain sufficient nutrients besides influencing the soil environment .

### Growing of Gliricidia as Green Manure Crop in Coconut Garden Under Littoral Sandy Soil

Coastal sandy soils, which are widespread along the coastal region of India, have poor physico-chemical properties, limiting the productivity. To mitigate this problem, investigations were conducted on the feasibility of growing gliricidia as a green manure crop under littoral sandy soil conditions at CPCRI, Kasaragod. *Gliricidia sepium* was established in two and three rows at 1 x 1 m spacing in a four year old coconut garden with a spacing of 7.5 m x 7.5 m. The treatment, three rows of gliricidia in between two rows of coconut palms with three prunings per year (February, June and October) resulted in higher biomass yield of 7970 kg/ha. Dry matter production and NPK yields were directly proportional to planting densities and inversely proportional to pruning intensities (Table 6). Coconut growth characters were not affected by intercropping of gliricidia (Table 7). Application of the gliricidia prunings from interspace of one hectare coconut garden to the coconut palms could meet a major portion of nitrogen (90%), part of phosphorous (25%) and potassium (15%) requirement of coconut palms.

### Recycling of Organic Wastes from Coconut Palm

Organic wastes from coconut palm are rich in lignin and are resistant to easy decomposition. If recycled fully, this waste biomass can meet a major portion of nitrogen and a part of other nutrient requirement of palms. Meaningful utilization is possible by using the biomass directly as mulch or after proper composting.

**Direct Utilization of Coconut Wastes as Mulch**

Most of the organic wastes from coconut have high moisture holding capacity and can be very profitably used as moisture regulators and conservators rather than nutrient sources. This gains more practical significance in the light of the fact that soils cannot be rejuvenated with organics in the absence of sufficient moisture. Similarly the full benefits from irrigation can be obtained only if there is sufficient quantity of soil organic matter. Keeping in mind the complementary roles of soil organic matter and moisture conservation coconut leaves, husks and coir pith can be utilized directly for mulching. Spreading of these materials in basin areas will protect the soil from direct sunlight and heavy rains. Mulches can reduce the loss of soil moisture and create good microclimate in soil for the proper growth of plant roots and soil flora and fauna. Over a period of time, mulches will decompose and assimilate into the soil organic matter reserves.

Coconut husks and coir pith can also be burried in trenches taken in between the rows of palms. Coir pith has 400-600 percent water holding capacity and this technique will be of immense value in long term moisture conservation. In addition, both these materials are rich in potash and would be available for plants over the years.

**Composted Biomass from Coconut Plantations as a Nutrient Source for the Palms**

Composting is one of the most popular methods of recycling the organic residues back to the soil. Compost is biologically decayed organic refuse and the process of composting leads to the production of brown and dark coloured humidified material which is valuable for supplementing plant nutrients. The time taken for completing the process of composting depends upon C:N ratio of the raw organic material. A C:N ratio of 30:1 in raw materials is most desirable for efficient composting. For materials with high C:N ratio, an external nutrient source, especially nitrogen must be added and this nutrient fortification will enhance microbial action. Use of microorganisms capable of producing cellulase and ligninase can enhance the degradation of organic wastes. Similarly, use of soil macrofauna such as earthworms capable of shredding the organic wastes and enhancing the surface area can reduce the composting period.

**Vermicomposting for Recycling Coconut Plantation Wastes**

Studies conducted at CPCRI, Kasaragod have revealed that coconut plantation wastes could be effectively converted into rich vermicompost using epigeic earthworms or compost worms such as *Eudrilus* spp. They can fully convert the wastes into vermicasts, leaving behind only midribs of the leaves. Nucleus cultures of the local strain of *Eudrilus* spp. capable of composting coconut plantation wastes are being supplied from CPCRI for a nominal cost. These worms can be multiplied fast in a 1:1 mixture of cow dung and decayed leaves, mulched properly with grasses.

A low cost technology has been standardized for vermicomposting the biomass from coconut palms left exposed to the action of weather in the field for about 3 months. The weathered wastes obtained during rainy seasons may be preferred. This waste can be used without chopping, thus saving a lot of labour. The coconut wastes used for oyster mushroom cultivation were also found suitable for vermicomposting. These organic wastes are to be treated with cow dung at the rate of 10 percent by weight in the form of slurry. The quantity of cow dung should not be more, as the earthworms will prefer cow dung, keeping aside the coconut palm wastes. The heap should be watered regularly to maintain sufficient moisture and allowed to undergo a preliminary decomposition. After giving one or two turnings to reduce the heat generated, the earthworms may be introduced at the rate of 1 kg per tonne of material. The compost bed should be mulched properly using any locally available plant material or gunny bags and has to be protected from direct sun light. Watering is to be done to maintain enough moisture. As full leaves are used for composting, compact mass is not formed allowing free movement of air in the bed. In about 2-3 months, compost will be ready leaving behind only midribs of the leaves. If the biomass used is old composting will be faster. Even the thick petioles are converted into vermicompost, but it will take more time based on the extent of weathering. On an average, 70 per cent recovery of vermicompost is obtained. The same technology for vermicomposting can be done in cement tanks, basins, heaps or large pits taken in the inter spaces of four coconut palms. If composting is done in the field itself, lot of labour required for transportation of the biomass and compost can be saved. This technology may be tried even in plantations with very limited irrigation facilities, as only a limited number of pits or trenches need to be watered. In coconut plantations with irrigation facilities, vermicomposting can be done in basins and palms can directly utilize the benefits.

The average nutrient composition of the vermicompost recovered was : N 1.8%, P 0.216%, K 0.16%, Organic carbon 17.84% and C:N ratio 9.95. Total microbial counts and beneficial microbial population were also more in the compost compared to the base material. Two types of active nitrogen fixing bacteria not commonly isolated from soils have also been found regularly associated with vermicasts. Vermicomposts contain nutrients in easily available forms in addition to a number of plant growth promoting substances and humic acids. Being granular and less bulky, they can be easily transported and incorporated into soils. Experiments conducted on polybag coconut seedlings have shown that vermicompost at 20 percent level can enhance seedling growth, health and root proliferation to a very great extent. The possibilities of using vermicompost in bearing palms for enhancing yield are immense.

**Enhancement of Composting of Lignin-Rich Biomass using Microbial Cultures**

Coir pith contains very less nitrogen and has large amounts of lignin and phytotoxic polyphenols and has to be composted before using as a manure. Exposure to rains and sunlight for many years results in loss of problematic chemicals and the use of weathered coir pith may be of advantages. Fresh coir pith has a wide C:N ratio (about 100:1) and for initiating microbial action, nitrogenous organic or inorganic materials have to be added. Additionally, fortification with rock phosphate at the rate of 10 kg per tonne of coir pith can also favour microbial action. The well known technology for composting of coir pith using *Pleurotus sajor caju* may be utilized for large scale composting. For composting one tonne of coir pith, 5 kg urea and 5 bottles of *Pleurotus* spawn is required. Hundred kilograms of coir pith is spread on a level land in a shaded place and one bottle of spawn is sprinkled over it. The spawn layer is covered with 100 kg coir pith and 1kg urea is sprinkled over it. This process is repeated five times to get a heap, which is protected from direct sun light and rain. Proper moisture has to be maintained in the heap and is allowed to undergo degradation for one month. This composted coir pith can be used as manure in coconut plantations and can increase the capability of soils to store moisture and nutrients.

A programme on composting of lignin-rich coconut wastes with biopolymer degrading microorganisms is in progress at CPCRI. Studies on fungi and bacteria involved in the natural decomposition of coconut wastes under field conditions resulted in the isolation and identification of fungal strains with high degradative capabilities as evidenced by ligninolytic and cellulolytic enzymes produced on lignin-rich materials. Efficient strains were used as microbial inoculants for composting of coir pith along with organic and inorganic amendments. Enrichment of compost was done with biofertilizers of asymbiotic diazotroph, *Beijerinckia indica* and phosphate solubilizing bacteria. The effectiveness of improved microbial technology was indicated by the lower C:N ratio and higher microbial load of bacteria, fungi, nitrogen fixers and phosphate solubilizers in the compost. Among the different biopolymer degrading fungal isolates tested, *Marasmus troyanus* was the most effective one for degradation of coir pith.

**Prospects of Application of Soil Biotechnologies in Organic Coconut Production**

A number of beneficial micro organisms are being increasingly used in crop production for improving the availability of nutrients, increasing nutrient use efficiency and biological control of soil-borne diseases. There are indications that coconut palms can also benefit from the use of such technologies. A number of studies have revealed that coconut growing soils harbour unusually very high diversity of beneficial microorganisms. These include vesicular arbuscular mycorrhizal fungi, phospahte solubilising bacteria and fungi, non-symbiotic nitrogen fixers such as *Beijerinckia indica*, associative nitrogen fixers such as *Azospirillum lipoferum*, *Azospirillum brasilense*, *Azospirillum amazonense*, *Herbaspirillum frisingense*, *Bacillus* spp., *Burkholderia* spp., *Azoarcus* spp., *Arthrobacter* spp., and many more which are yet to be identified. A number of these bacteria have been observed to be multifunctional. Many of these bacteria are unique in that they are able to fix nitrogen even in the presence of nitrogenous fertilizers and produce a variety of plant growth promoting substances. They have been found to enhance root growth and secondary root formation when inoculated to coconut plants. All these effects on plants can result in increased nutrient use efficiency, benefiting the whole system. Thus, these inoculants may have importance even when chemical fertilizers are used. Exopolysaccharides producing *Beijerinckia indica* is very common in coconut soils and by favouring their activity, soil physical properties can be improved in addition to the benefits from nitrogen fixation. Use of phosphate solubilizing bacteria along with low cost rock phosphates can reduce the cost of cultivation. The coconut farmers can benefit from these beneficial microflora by proper recycling of organic wastes and ensuring proper moisture levels in soil. Even if nitrogen addition to the system through biological nitrogen fixation is low, this is the only mechanism through which newly created nitrogen is added to the system and these nitrogen fixers may influence coconut yield in soils very poor in nitrogen. Isolation and identification of microbial strains capable of promoting growth and health of the palms and formulation of effective bioinoculants based on them will in future form an important aspect of organic farming research for coconut palm.

**Conclusions**

Organic cultivation of coconut palms is much easier than any other crop and possibilities of achieving sustainability in production through this technology are immense. While converting into organic farming, the challenge is to provide the full nutritional requirements through internal organic sources. It may not be possible especially in commercial large scale farms, and nutrient elements that are deficient in the ecosystem may have to be supplied from external sources for realising very high yields. If reasonable yield is sufficient, it may be possible to meet all the nutrient requirements from organic residues generated from the plantation.

Long term effects of organic cultivation on coconut and copra yield and oil quality and soil properties are to be studied in detail. Much more information on influence of organic farming on incidence/ severity/ control of various pests and diseases in palms is required. Strategies for control of possible increase in the incidence of rhinoceros beetle in organic farms are to be worked out.

Participatory technology development may be needed for spreading the benefits of organic cultivation among farmers. Achieving sustainability in coconut production cannot be without a price. So, small scale farmers may need generous Government support and subsidies in initial stages. Organic farming may not be that economical unless provisions are made for irrigation and generating organic manures within the farm itself. Organic manures being bulky, unless they are generated at the site of use, their transportation and application will be very costly. Research in the direction of production of good quality manures and composts in shortest period should be given importance . As the diffusion of any technology will depend on the satisfaction of farmers with regard to the economics of cultivation, they should be assured of encouraging price support for their organic produce and products. Elaborate market promotion for organic coconut products may be needed to catch up in the markets.

*Vermicomposting*

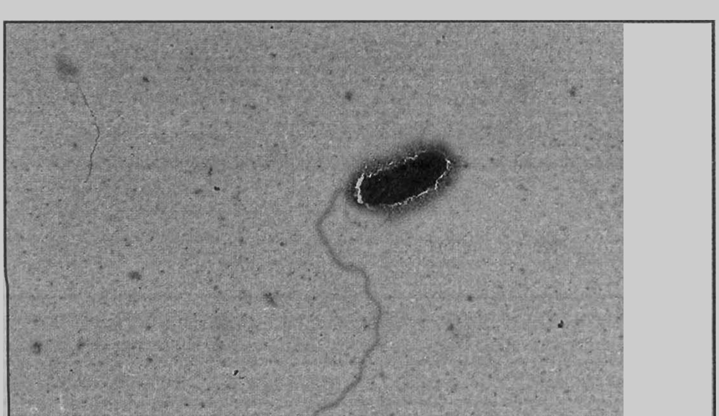
*Direct utilization of coconut leaves as mulch*

*Heap method of vermicomposting in coconut gardens*

*Gliricidia grown as a alley crop in littoral sandy soils*

*Pit method of vermicomposting in the interspaces of coconut palms*

*Calopogonium mucunoides grown in coconut basins for green manuring*



*Nitrogen fixing and plant growth promoting bacteria Azospirillum spp. isolated from coconut palm*

*Vermicompost produced from coconut palm wastes*