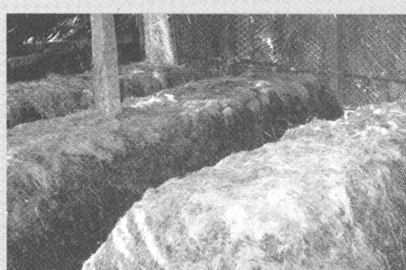
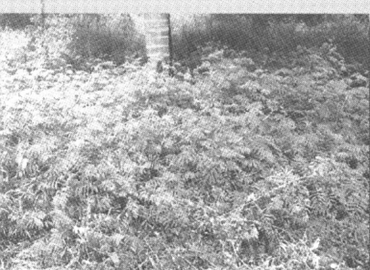
ORGANIC FARMING TECHNOLOGIES IN COCONUT





भाकृअनुप
ICAR

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

KASARAGOD - 671 124, KERALA, INDIA

केरोफअसं
CPCRI

ORGANIC FARMING TECHNOLOGIES IN COCONUT

GEORGE V. THOMAS
S.R. PRABHU
P. SUBRAMANIAN
ROHINI IYER

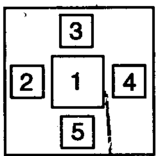
ICAR
CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD - 671 124, KERALA, INDIA
CPCRI

Published by:

Dr. V. Rajagopal
Director
Central Plantation Crops Research Institute
Kasaragod - 671 124
Kerala, India.

Photo:

Front cover:



1. Vermicompost application in coconut basin
2. *Mimosa invisa* in coconut basin
3. Large scale composting of coir pith with microbial inoculants and amendments
4. Mass multiplication of *Trichoderma harzianum* on sorghum grains
5. Vermicompost produced from coconut wastes

Cover design:

C.H. Amarnath

Photo credit:

K. Shyama Prasad

October, 2001

ATIC Series Publication No. 4
Prepared by Dr. S. Arulraj, Head of Division (Social Sciences)
- under the scheme for "Establishing Agricultural Technology Information Centre" (ATIC)
- National Agricultural Technology Project (NATP)

ORGANIC FARMING TECHNOLOGIES IN COCONUT

The importance of nutrient management in coconut gardens to realise profitable returns has been well recognized. However, the consumption of inorganic fertilizers is very low in coconut plantations mainly due to the cost factor and fluctuating price trends of the produce. The adverse effects of continuous use of chemical fertilizers on soil physical and biological properties and its effect on performance of crops have been a matter of concern throughout the world. To maintain and improve soil fertility and to achieve sustainable production in coconut, organic manure application is of utmost importance. The use of organic manures in coconut cultivation is now limited due to non-availability of organic manures in sufficient quantities, higher cost and transportation-related expenses. Research carried out at CPCRI suggests the feasibility of recycling the waste biomass available in coconut plantations to meet the nutrient requirement of coconut palm. Biomass generation through green manures is also feasible in a coconut plantation with the cultivation of leguminous green manure crops. These crops have the ability to fix atmospheric nitrogen in association with the root nodule bacteria, *Rhizobium*. Biofertilizers and biopesticides also could form vital inputs in organic cultivation of coconut.

1. Relevance of organic farming in coconut cultivation

Coconut exports nutrients to the above ground parts continuously from a limited volume of soil throughout its existence. Unlike other field crops, there is no critical stage of nutrient requirement for coconut palm. Since the palm produces flowers and leaves every month, nutrition is important throughout the year. It is, therefore essential that a nutritionally rich environment is provided in the feeding zone (root zone) of coconut continuously to realize adequate yields. It is reported that 56 kg N, 12 kg P, 70 kg K, 34 kg Ca and 12.5 kg Mg are removed annually by the coconut palm from one hectare. For coconut palms, the nutrients of importance can be arranged as potassium, nitrogen, phosphorus, calcium and magnesium. The fertilizer use efficiency for coconut is very low. In addition to this, straight fertilizers supply only NPK and do not have an impact on soil physical properties. The nutrients held in organic combinations become available to the plants slowly over many cropping seasons as a result of the natural control over mineralization effected by the heterotrophic organisms through nutrient immobilization. In the context of sustainable agriculture, the interest generated in sustainable coconut production by adopting organic farming methods is considered a welcome sign.

2. Concept of organic farming

The concept of the soil as a living system that develops the activities of beneficial organisms is the central dogma in 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 harbours a variety of insects, earthworms, enchytraeids, nematodes, fungi, actinomycetes, bacteria and a host of other known and unknown organisms, which together support plant life through a variety of physical and biochemical activities. Historically, much attention was paid to the impact 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 number of soil flora and fauna are increasingly considered as true indicators of soil quality or soil health. Biologically mediated processes form the key to the ecological functioning of soil and soil biological activity is the driving force in the decomposition of organic matter, formation of humus, nutrient transformation, 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 soil, 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.

The basic principle of organic farming is that if soil is fed properly with organic manures, it will in turn ensure good nutrition for plants. By supplying the soil with required amounts of organic manures, nature is encouraged to build up soil biodiversity and thus develop its own capabilities and mechanisms to support plant growth by supplying nutrients and prevention of nutrient loss etc. In actual practice, the number and activity of beneficial soil organisms can be increased either directly by inoculation of pre-tested efficient organisms (*eg.*, biofertilizers) or indirectly by adding organic manures, which serve as energy and nutrient source for the native organisms. By following organic farming technologies, one can ensure availability of enough organic wastes for recycling, create favourable conditions for their early decomposition and favour the growth and activity of an array of soil flora and fauna. Strictly speaking, use of chemical fertilizers and pesticides are not allowed to be used in organic farming. It is a system of farming where the soil is made physically fit, chemically balanced and biologically active. The fertility of the soil is maintained by using farm yard manure/decomposed organic matter/ vermicompost / rhizobium cultures and the like. We can control pests by using parasites, predators, products of neem, tobacco decoction, garlic, red chilli powder etc. Diseases can also be controlled by prophylactic measures including crop rotation, growing trap crops and use of bio-agents like *Trichoderma*, pheromones and products of garlic.

3. Recycling of Organic Wastes from Coconut

(a) Availability of organic residues in coconut gardens

The availability of waste biomass from a well managed coconut garden with 175 trees/ ha has been estimated as 14 tonnes / ha/yr in the form of leaves, spathe, bunch waste and husk of nuts. A considerable portion of husk is used for extraction of coir fibre. The by-product of coir processing factories, coir dust is usually dumped without any use. It has been estimated that 7.5 lakh tonnes of coir dust is available in the country from various coir defibering units. The total availability of waste biomass from 1.81 million hectare of coconut plantation in the country has been estimated as 14.36 million tonnes annually. The natural decomposition of these wastes and the nutrient release are very slow due to the high lignin content and the nature of lignocellulose complex of the coconut waste materials. Substantial saving in terms of fertilizer input is possible through effective recycling of the waste biomass.

Additional quantity of waste biomass is available from the inter and mixed crops forming the components of coconut based cropping systems. Under the coconut-cocoa mixed cropping system, the availability of cocoa leaf litter was estimated as 820 and 1980 kg/ha/yr on dry weight basis in single and double hedge systems. Crop residues to the level of 11.6 to 16.5 t/ha/yr are available from a coconut based high density multispecies cropping system involving coconut, clove, banana and pineapple. In an ongoing experiment on coconut based mixed farming of 1.2 hectares involving coconut, fodder grass, dairy, poultry and rabbitry, 15 tonnes of farm yard manure and 2 tonnes of poultry manure and 50,000 litres of cow urine and cow shed washings are obtained annually. If effectively recycled, these can supply 125 kg N, 78 kg P_2O_5 and 115 kg K_2O. Recycling these residues in the plantation itself will help to meet major nutrient demand of the crop.

The organic wastes can be directly utilized as mulch or converted into compost by employing earthworms or microbial cultures. Addition of nitrogen through biological nitrogen fixation can be favoured by growing green manure legumes and use of biofertilizers based on asymbiotic and associative symbiotic nitrogen fixing bacteria.

(b) Vermicomposting

A low cost technique for large scale vermicomposting of coconut wastes in cement tanks was standardized at CPCRI using a local species of epigeic earthworm or compost worm belonging to *Eudrilus* sp. Earthworms can be multiplied in a mixture of cow dung and decayed leaves in 1:1 ratio taken in cement tub, wooden box or plastic bucket with drainage facilities. Worms should be introduced at the rate of 50 numbers per 10 kg of organic wastes. Within 1-2 months, the earthworm multiplies 300 times, which can be used for large scale composting. Fresh vermicomposts contain plenty of earthworm cocoons and hence can also be used as nucleus culture instead of live earthworms. This has advantages, especially when worms are to be transported to a long distance. Each cocoon will hatch to give 2-3 juveniles and when fresh vermicompost is incubated with cow dung, in a couple of months, enough earthworms required to initiate vermicomposting can be obtained.

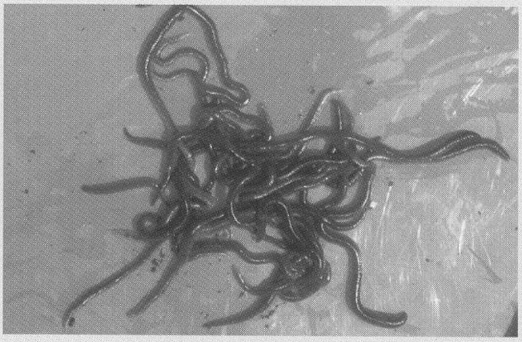
The coconut lignocellulosic biomass weathered for three to four months in rain can be used for vermicomposting. These organic wastes are to be treated with cow dung at the rate of 10 percent by weight in the form of slurry. After two to three weeks of initial decomposition, the earthworms may be introduced at the rate of 1 kg per ton of the material. The compost bed should be mulched properly and watering is to be done regularly to maintain enough moisture. Due to earthworm activity, the organic wastes used will be converted to granular vermicastings in a period of 60 days, leaving only midribs of leaves. The vermicompost thus produced had a nutrient content of 1.8% N, 0.21% P and 0.16% K with a C: N ratio of 9.9. *In situ* recycling of coconut wastes by vermicomposting in trenches dug in interspaces of four coconut palms yielded 70% recovery in a composting period of 90 days. In coconut plantations with irrigation facilities, vermicomposting can be done in basins and palms can directly utilize the benefits. This enables disposal of coconut wastes in a less expensive and eco-friendly manner with the benefit of producing high quality manure in coconut plantation.

(C) Composting of coir pith

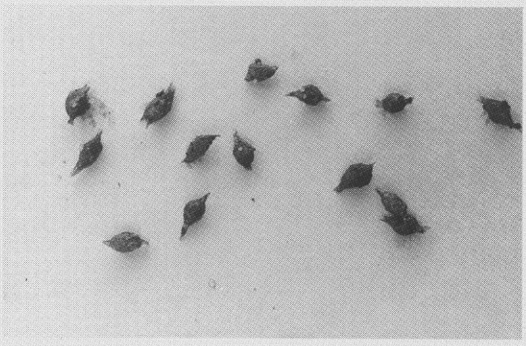
Coir pith which accumulates as a problematic waste in coir defibering units can be converted to organic manure by composting. Large scale composting of coir pith can be done either in cement tanks or by the heap method in a shaded place. Coir pith obtained from coir processing units are treated with lime (0.5%), urea(0.5%), rock phosphate (0.5%) and legume biomass (*Glyricidia* leaves) or cowdung or compost from previous batch (10%) and moistened. The treated coir pith is sprayed with 1% jaggery solution and mixed with fungal inoculum at 0.2 % level 15 days after the amendment. Regular watering is done to keep the heap moist. The raw coir pith with a C:N ratio of 108:1 would turn into compost having a C:N ratio 15:1 and high microbial population within a period of 40-50 days (Table 1). *Marasmiellus troyanus*, an efficient producer of ligninolytic and cellulolytic enzymes, isolated from decomposing coconut waste was effective in composting of coir pith. A local isolate of *Trichoderma* species was also effective to compost coir pith. Microbial enrichment of coir pith compost with N-fixing bacteria and phosphate solubilisers enabled production of good quality compost with better manurial value. Studies on naturally decomposing coconut wastes resulted in the isolation of efficient ligninolytic and cellulolytic fungi sucls as *Lepista* sp., *Lentinus Squarrosulus Schizophyllum commune* etc. with degradation potential.

Coir pith can also be composted using earthworms. Coir pith treated with lime and rock phosphate @ 0.5% each and incubated for three weeks has to be mixed with cow dung @10% and fresh vermicompost @10%. This mixture has to be layered with uncut coconut leaves @20% to facilitate aeration in the bed. The earthworm *Eudrilus* spp. has to be introduced at the rate of 1000 numbers/ tonne of organic materials and the bed should be mulched and protected from direct sun light. Moisture has to be maintained at 50% by regular irrigation. Earthworms form burrows in the bed and vermicastings appear as surface casts. A granular vermicompost with 1.2% nitrogen and 16.7:1 C:N ratio can be obtained in two months.

Biomass available for recycling in coconut plantations



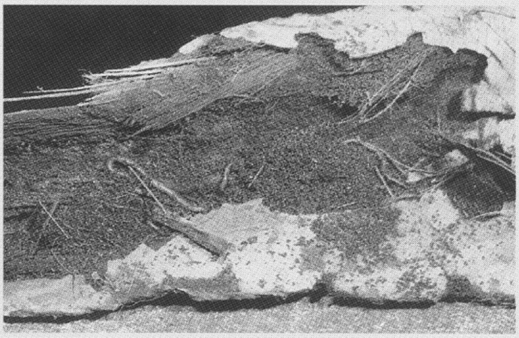
Eudrilus sp. capable of composting coconut palm wastes



Cocoons of earthworm

Mass multiplication of earthworms in 1:1 mixture of cow dung and decayed leaves for supplying to farmers

Heap method of vermicomposting of coconut leaves



Local earthworm species feeding on coconut petiole

Granular vermicastings

Application of spawn for composting of coir pith

Table 1 Nutrient content and microbial characteristics of composted coir pith produced by microbial inoculation and amendments

Particulars	Raw coir pith	Composted coir pith
Carbon (%)	28.12	19.77
Nitrogen (%)	0.26	1.25
C:N ratio	108.15	15.87
Phosphorus(%)	0.10	0.36
Potassium(%)	0.28	0.25
Microbial load(cfu/g)		
Bacteria		16×10^7
Fungi		55×10^3
Actinomycetes		15×10^5
P-solubilizers		53×10^5
Asymbiotic N_2-fixers		31×10^4

(d) Oyster mushroom cultivation for recycling of coconut waste

Another approach for recycling of coconut wastes is by utilization of lignocellulosic biomass for oyster mushroom cultivation and further conversion of the spent substrate to organic manure by composting or vermicomposting. Coconut leaf stalk, bunch waste or a combination of leaflets + bunch waste were better substrates for oyster mushroom cultivation, which gave a biological efficiency (BE) of conversion of 55-70%. The *Pleurotus* species found suitable for mushroom production on coconut wastes were *P. florida, P. sajor caju, P.flabellatus and P.eous*. Mushroom produced using the coconut waste had a protein content of 20-30% on dry weight basis. Low cost mushroom house built exclusively of coconut materials inside coconut plantations provide ideal conditions for mushroom cultivation. Spent substrate was composted and analysis of composted spent substrate revealed enhanced nutrient status as evidenced by higher content of NPK and low C:N ratio. The composted spent substrate had N content of 1.0 to 1.29 % and P content of 0.08 to 0.13 % compared to 0.45% N and 0.05 % P in untreated substrate. The composted spent substrate also contained higher levels of micronutrients such as Fe, Zn, Cu and Mn when compared to that of the untreated substrate (Table 2).

Table 2 Nutrient content of spent substrates obtained from cultivation of *Pleurotus sajor caju* on coconut bunch waste

Nutrient	Content in spent substrate	Content in control
Nitrogen	1.29 %	0.45%
Phosphorus	0.13%	0.05%
Calcium	0.653%	0.109%
Magnesium	0.267%	0.083%
Iron	743.98ppm	332.82ppm
Zinc	30.63ppm	8.04ppm
Copper	24.30ppm	9.75ppm
Manganese	184.98ppm	46.98ppm

(e) Direct utilization of coconut palm wastes

(i) Coconut wastes as mulch in plantations

Coconut leaves, husk and coir pith could be utilised as mulch to reduce the loss of soil moisture and create conditions for proper root growth and proliferation of soil flora and fauna. The husk can also be used as a surface mulch around the base of the palms. Husk in a single layer is placed with convex side up around the palm upto a radius of 2 m from the base. Decomposition of the mulch after a period of time result in enrichment of soil organic matter pool.

(ii) Husk burial

Burial of husk in trenches in between the rows of palms is highly effective for moisture conservation in coconut gardens. Husk burying is done at the beginning of the monsoon in linear trenches of 1.5 to 2 m wide and about 0.3 to 0.5 m deep between rows of palms with concave side of husk facing upwards. Each layer is covered with soil. In a period of 5-6 years, the husk gets decomposed completely and the nutrients, particularly potassium become available to the coconut palm. Coconut husk is an important source of potash which becomes available to the palms over a period of time.

(f) Effect of organics on soil properties

The effectiveness of organic manuring to enhance nutrient content of soil and soil physical conditions was demonstrated in littoral sandy soil with different organic amendments viz. forest leaves, coconut sheddings, cattle manure and coir pith in combination with inorganics. The incorporation of organics significantly enhanced the content of organic carbon, available N, Fe, Mn and exchangeable Ca and Mg in littoral sandy soil. Organic amendment was also effective in increasing nutrient content and water holding capacity and in decreasing the bulk density of soil as compared to application of inorganics alone(Table 3). Organic manures also had profound influence on the establishment, growth and flowering of coconut seedlings as revealed in a 10 year study.

Table 3 Influence of organic manuring on the nutrient content and physical properties 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
Water holding capacity (%)	33.80	27.10	27.20	26.50	23.40
Bulk density(g/cc)	1.37	1.49	1.50	1.56	1.60

4. Utilization of legume-*Rhizobium* symbiosis in coconut cultivation

(a) Basin management with leguminous crops

The technique for utilization of leguminous cover crops as green manures to supply biologically fixed nitrogen and easily decomposable biomass to coconut was standardized at CPCRI. It involves cultivation of leguminous creepers such as *Pueraria phaseoloides, Mimosa invisa* and *Calopogonium mucunoides* in coconut basins during the monsoon period from June to October and incorporation of legume biomass in respective basins. During a growth period of 140-150 days, the promising legumes generated 15-28 kg of biomass and 102-197g of nitrogen in the basin of a coconut palm. (Table 4). A field experiment conducted in a coconut plantation in an acidic laterite soil type revealed the feasibility of substituting upto 50% of fertilizer nitrogen with the nitrogen contributed by leguminous green manures. *M. invisa* and *P. phaseoloides* are well nodulated by native rhizobia in acidic coconut soils. If nodulation is poor, inoculation with

Table 4 : Biomass and nitrogen contribution of green manure legumes in coconut basins (1.8 meters around the trunk)

Sl. No.	Legume species	Laterite soil		Sandy soil	
		Biomass kg/basin	Nitrogen g/basin	Biomass kg/basin	Nitrogen g/basin
1	*Calopogonium 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

biofertilizers of rhizobia will result in improved nodulation and enhanced biomass and nitrogen yield. It is also possible to generate significant quantities of biomass by growing these legumes in the interspaces of coconut palms. If the germination of seeds of *Calopogonium* and *Pueraria* is poor, scarification of seeds by treatment with concentrated sulphuric acid for 5 minutes is necessary to obtain higher rate of germination. Legumes such as cowpea, sunnhemp etc. can also be cultivated in coconut gardens to generate large quantities of biomass for recycling. Easily decomposable nitrogen rich green manure can be produced by this method at the site of need itself without any additional land requirement and expenditure. Incorporation of these green manures has been shown to enhance the counts of total microflora, asymbiotic nitrogen fixers, P-solubilizers and enzyme activities and vesicular-arbuscular mycorrhizal infection and counts (Table 5), thus enhancing the benefits from these beneficial microorganisms in coconut root regions.

Table 5. Effect of green manure incorporation on microbial population, enzyme activity and VAM infection and counts in coconut rhizosphere

Parameters tested	Green manures incorporated			Control
	P.phaseoloides	*C.mucunoides*	*M.invisa*	
Bacteria(x 10^6)	39.25	16.00	2.84	18.61
Fungi(x 10^4)	8.8	11.39	10.12	2.30
Actinomycetes(x 10^4)	18.75	14.67	5.27	6.86
Asymbiotic N - fixers(x 10^3)	69.30	63.49	30.12	41.44
P-solubilizing fungi(x 10^3)	7.85	4.15	6.38	1.17
P-solubilizing bacteria (x 10^4)	7.51	6.16	4.47	1.75
Endogenous dehydrogenase activity (µg/TPF/g oven dry soil)	4.07	3.28	3.31	1.56
Dehydrogenase activity in response to glucose (µg/TPF/g oven dry soil)	22.22	29.55	11.97	5.45
VAM spore count/50ml soil	240	362	401	271
VAM infection in coconut roots(%)	62.7	79.4	73.6	69.7

(b) *Glyricidia* as green manure crop

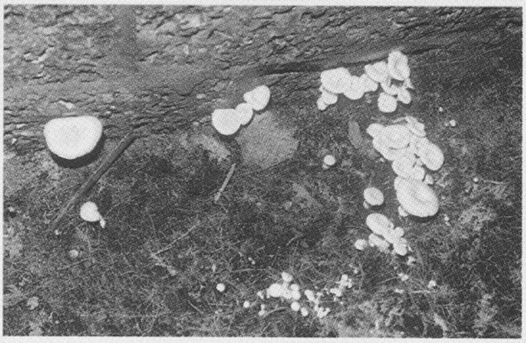
Generation of large quantities of nitrogen rich biomass is also possible through the cultivation of the fast growing leguminous tree crop, *Glyricidia* in the coconut plantations. It can also be grown in littoral sandy soils where no other green manure can establish. The planting density and pruning frequency to obtain higher biomass yield from *Glyricidia sepium* when grown as green manure crop in coconut plantation in littoral sandy soil was standardized. The treatment, three rows of *Glyricidia* in between two rows of coconut palms with three prunings per year (February, June and October) resulted in higher biomass yield of 7.9 t/ha/yr (Table 6). Application of *Glyricidia* prunings from interspace of one hectare of coconut garden can meet a major portion of nitrogen (90%), part of phosphorus (25%) and potassium (15%) requirement of coconut palm. Growing *Glyricidia* in the interspaces of coconut did not affect the growth characters of coconut.

Table 6 Effect of pruning regimes and planting density on biomass yield of *Glyricidia* (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

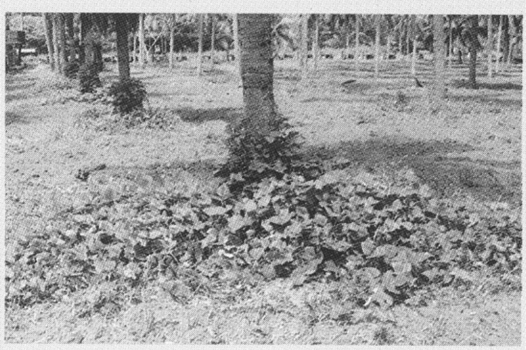
5. Biofertilizers

Microorganisms carry out many biochemical transformations in soil which result in enhanced nutrient availability and crop growth. The group of microorganisms responsible for nitrogen fixation, phosphorus mobilization and production of plant growth promoting substances are being put to use in the form of biofertilizers. They are preparations containing living cells of beneficial microorganisms multiplied in suitable carriers for use as inoculants in crop production. A large array of bacteria possess the potential to enhance growth and health of agricultural crops that are now known as plant growth promoting rhizobacteria (PGPR). They are naturally occurring free-living soil microorganisms which are capable of colonizing roots and enhancing plant growth when added to seeds, roots or tubers. The direct mechanism of improving crop stand by many of these microorganisms is by producing and secreting plant growth promoting substances (phytohormones) such as auxins, gibberellins, cytokinins, ethylene and also vitamins; 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. PGPRs also influence plant growth by indirect mechanisms such

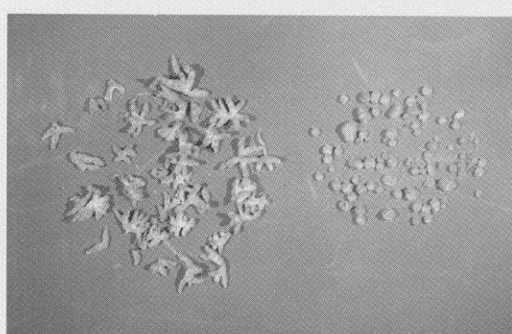


Lepista sp. growing on coir pith

Edible fruiting bodies of *Pleurotus opuntia* on coconut wastes

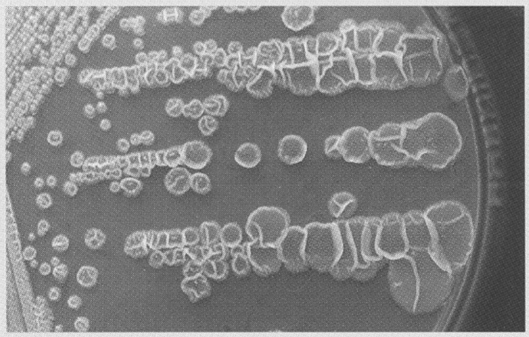


Cowpea as green manure crop in coconut basin

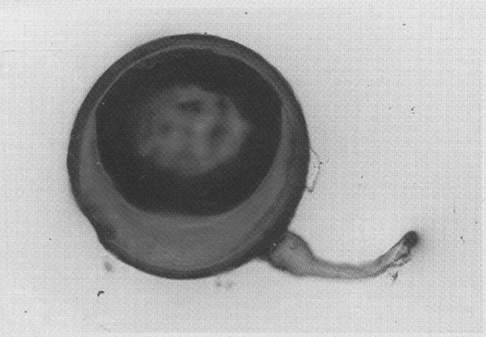


Effective root nodules of Calopogonium and mimosa

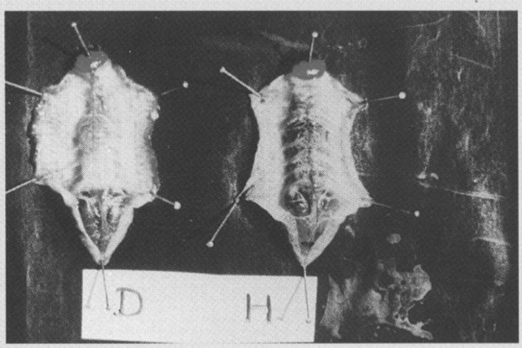
Alley cropping of Glyricidia in coastal sandy soil



Typical colonies of N_2 - fixing and obligately acidophilic *Azospirillum amazonense* associated with coconut palm



Spore of arbuscular-mycorrhizal fungus *Gigaspora* sp. associated with coconut



Dissected Oryctes grubs - D - Baculovirus diseased, H - healthy as suppression of bacterial, fungal and nematode pathogens (biocontrol) by the production of various metabolites, by induced systemic resistance and/or by competing with pathogens for nutrients or for colonization space. These characters differentiate them from many other microorganisms that are also found in the rhizosphere.

Coconut roots have been shown to support high population of microorganisms Many of the bacterial and fungal isolates are shown to possess plant growth promoting capacity. Coconut, which is grown under a wide range of environmental conditions, is targeted for successful application of biofertilizers. Among the microorganisms that are promising enough to fit well into the horticultural crop production systems are free-living and associative microorganisms with specific functions, such as nitrogen fixation, phosphorus mobilization and production of growth promoting substances.

Free-living and root-associated beneficial microbes in coconut soils

The root region of coconut palm is inhabited by a number of free living and associative symbiotic nitrogen-fixing bacteria having nitrogenase activity. The association of N -fixing *Azospirillum amazonense* with the roots of coconut palm has recently been confirmed . The other associative nitrogen fixers include *Azospirillum lipoferum, Azospirillum brasilense, Herbaspirillum frisingense, Bacillus* spp., *Burkholderia* spp., *Azoarcus* spp., *Arthrobacter* spp. and many more which are yet to be identified. Some of these are capable of fixing nitrogen even in the presence of nitrogen fertilizer. These organisms may have additive or synergistic effects on plant growth and health if they function in concert in the rhizosphere of coconut palms.

Soil amendments as well as farming practices also bring about a protracted change in rhizosphere microflora, which favour the growth of specific microorganisms, thus leading to better plant growth and crop yield. For example, organic amendments like cow dung increase VA-mycorrhizal colonization as well as the population of phosphate solubilizing bacteria in the root zone of coconut palms. Other organic amendments such as coir pith, neem cake, green manures etc. can be combined with microbial inoculants like *Beijerinckia indica* for improving the nitrogen fixation by indigenous diazotrophs in coconut soil.

The activities and positive effects of these beneficial microorganisms become more tangible in crop mixing or mixed farming in coconut as the component crops continually add plant residues to the soil which undergo organic recycling. This leads to alterations in the composition of the rhizosphere and has important and exciting implications in the manner that could possibly promote the growth and number of beneficial microorganisms. Also in mixed cropping, nitrogen-fixing bacteria dominated by the *Beijerinckia* group and phosphate-solubilizers such as *Pseudomonas* sp., *Bacillus* sp., *Aspergillus* sp. and *Penicillium* sp. are higher in numbers. Not only this, higher inhibition potential of resident soil bacteria to phytopathogens is observed, as compared to coconut monocropping. When coconut is grown with cacao, rhizosphere activity increases and a better mobilization of phosphate coupled with fixation of nitrogen and production of growth promoting substances (GLS and IAA) in rhizosphere is reflected in terms of enhanced yield. An indole-acetic-acid (IAA) producing *Escherichia* sp. is associated with the root surface of coconut and the rhizospheric *Aspergillus flavus* and A. *fumigatus*, produce gibberellin-like substances (GLS).

Microbial combinations may have very great potential for plant growth enhancement. While raising coconut seedlings in coir dust-soil mixture, *Beijerinckia indica* and associative diazotrophs such as *Azospirillum, Arthrobacter, Azoarcus, Herbaspirillum, Bacillus, Burkholderia* and *Pseudomonas* are promising microbial inoculants which enhance the growth and performance of seedlings. Additive growth benefits can be obtained by inoculating a plant growth-promoting bacterium in combination with phosphate-solubilizing bacteria and associative nitrogen-fixing bacteria. For additive effects, the compost prepared from coir-pith and other coconut wastes can be enriched with nitrogen-fixing bacteria like *Beijerinckia indica* and also phosphate-solubilizing bacteria, for application in coconut basins. Some rhizosphere microorganisms may have multiple functions as in the case of mycorrhizal fungi , which can enhance the absorption of phosphate from soil, produce ethylene and hormones and are also effective against root pathogens. Such plant growth promoters could be exploited to their full potential for use in coconut-based crop production systems.

It is time to explore the possibility of including the microscopic agents of vast potential in coconut farming, with a view to facilitating the reconstitution of rhizosphere microflora dominated by already proven beneficial organisms for a sustainable coconut farming.

6. Biopesticides

Biopesticides are those pesticides which are of biological origin, as against the chemical or synthesized compounds.These include microorganisms, parasites, predators and natural plant -based pesticides from neem, tobacco and garlic etc., which don't harm the environment but effectively reduce pest population. These have many merits over the conventional chemicals used for pest control. They are biodegradable, target - specific and can be locally produced. We have a number of instances where they have been proven as effective control agents in managing coconut pests and diseases.

In the case of rhinoceros beetle, release of 10-15 Baculovirus infected beetles/hectare has been found to be an effective measure in checking the population of the beetle.

Metarrhizium anisopliae, or the green muscardine fungus is another biocontrol agent which can infect all stages of rhinoceros beetle. This fungus can be easily multiplied in coconut water, tapioca chips etc. and spores can be harvested and treated in the beetle breeding grounds @10^{11} spores/m^3. On inoculating the fungus in decaying organic matter, they thrive well and cause a good degree of mycoses of the grubs resulting in reduction of black beetle population.

Clerodendron infortunatum, a commonly found weed in Kerala is another promising biocontrol agent. Grubs of black beetle become deformed and sterile when fed on feed containing this plant. This plant with root, shoot, leaves and flowers can be incorporated in the breeding grounds of the beetle @ 5 percent (w/w) and the larvae that hatch out in such pits will be affected by the contaminated feed.

Pheromones are behaviour modifying chemicals aiding in attraction of the beetles/weevils. The aggregation pheromones secreted by rhinoceros beetle and red weevil have been studied for their structural configuration and they have been synthesised and are now in use is the field on a commercial scale. For best results, one pheromone trap may be installed per hectare of coconut plantation to mass trap and destroy the beetles.

Biological control by the release of larval stage- specific parasitoids is a major component of IPM. The larval parasite *Goniozus nephantidis*, the pre pupal parasite *Elasmus nephantidis* and the pupal parasite *Brachymeria nosatoi* are released at the optimum ratios ie., 20,49, and 32 numbers for every 100 larvae, pre pupae and pupae respectively at fortnightly intervals, depending on the pest availability in the field. These egg and larval parasitoids are being multiplied and distributed in large numbers for use in affected gardens.

Neem oil - garlic - soap emulsion has emerged as one of the potent measures for the control of the eriophyid mite *Aceria guerreronis*. *Hirsutella thompsonii*, a fungus has been found to be an effective microbial agent for annihilating this pest.

Increased use of organic amendments like neem and marotti (*Hydnocarpus*) oil cakes and farm yard manure helped in the integrated management of burrowing nematode, *Radopholus similis* in coconut.

Biocontrol measures have been formulated for stem bleeding disease also. *Gliocladium virens, Trichoderma hamatum* and *T. harzianum* have been found to be very effective in reducing the population of *Theilaviopsis paradoxa* in the soil. These antagonistic fungi thrive very well in neem cake supplemented with a small quantity of rice/wheat bran thus effecting their multiplication an easy task. At the same time, neem cake does not favour the growth of *T. paradoxa*, the causal agent of the stem bleeding disease of coconut. *Trichoderma harzianum* has been found to control the multiplication of *Ganoderma lucidum*, the causal organism of basal stem rot in sick soils. When combined with Phosphobacterium or Plant Growth Promoting Rhizobacteria (PGPR), synergistic effects have been noticed.

7. Inspection and certification in organic coconut cultivation

Inspection and certification of organic gardens and the products are the only criteria for the authentication of a product as organic. For getting premium price in international market, the produce should be certified as organic. The concept of organic agriculture and organic food processing is based on certain specific norms and standards, which varies from country to country. The main focus of organic certification is to give to the farmer access to the premium organic market and to protect the interest of the consumers, by providing them genuine organic products.

The International Federation of Organic Agriculture Movements (IFOAM) has framed certain basic standards. They provide a frame work for certification programmes worldwide to develop their own national or regional standards. The IFOAM-India has prepared and adopted the basic standards as applicable to Indian conditions, which were drafted by the National Standards Committee. A list of materials permitted /banned by IFOAM -India for use in organic cultivation for soil conditioning and pest disease control are listed in Tables 7 and 8 respectively.

8. How to grow coconut organically

Based on the research results and farmers' experience, a package of recommendations could be made for organic cultivation of coconut palms.

Selection of seed gardens and seed nuts

- ➢ Select seed nuts from palms in an organically grown plantation having high proportion of heavy yielders without the incidence of diseases and pests
- ➢ Select regular bearers in the age group of 20-50 years with annual yield of greater than 80 nuts/palm under rainfed conditions and 120 nuts under irrigated conditions. The copra content should not be less than 150 g per nut.
- ➢ Collect fully mature (12 months old) nuts as seed nuts from January to April (under west coast conditions).

Raising of nursery

- Raise nursery by sowing seed nuts at a spacing of 40x30 cm during May-June, either vertically or horizontally in 20-25 cm depth trenches in nursery beds.
- Grow green manure crops in between rows.
- Vigorous seedlings can be raised in black poly bags of 60x45cm size of 500 gauge thickness using soil + coir pith mixture in 1:1 ratio. Inoculation of biofertilizers of *Azospirillum, Beijerinckia* and phosphobacteria will result in production of vigorous seedlings.

Table 7 Products for use in soil fertility management

Banned	Permitted
chemical and synthetic fertilizers, sewage sludge, farm yard manure, slurry, urine, compost, Calcified sea weed, straw, coir pith, plantation products, oil cakes, mulches and other crop residues — obtained from non-organic farms	farm yard manure slurry urine poultry manure vermicompost composts produced from organic residues green manure and green leaf manure bio-dynamic preparations, azolla straw mulches from sugarcane trash kitchen waste coming from organically produced stuff, organic composted tea/coffee wastes coir pith plantation by-products and wastes (all of these should be produced on the farm)
Restricted	**Restricted**
Organically produced mushroom beds oil cake & milled by-products human excrement (risk of contamination) biofertilizers saw dust organic by-products of food and textile industries without any synthetic additives Farm yard manure, Slurry, Urine, Compost, calcified sea weed, straw, coir pith, plantation products, oil cakes, mulches and other crop residues — obtained from other organic farms	blood meal, meat meal, and bone meal brought from other sources and without preservatives fish and fish products without preservatives guano gypsum (risk of depletion of natural resources) lime stone (risk of contamination) magnesium rock (risk of contamination) pulverised rock natural phosphates such as rock phosphates mineral potassium with low chlorine content calcareous and magnesium amendments, basic slag trace elements.

Field planting

- Planting in square system at a spacing of 7.5x7.5m will accommodate 175 palms in a hectare. Wider spacing can be adopted to accommodate mixed crops.
- The recommended pit size in normal soil is 1m x 1m x 1m. Plant seedlings during May-June after filling the pits upto 60cm with top soil amended with FYM/ compost and biofertilizers. Coconut husk can be buried on the sides.
- For planting, select one year old seedlings (those germinated before five months) having at least six leaves and girth of 10 cm at collar.

Care of young gardens

- During summer, provide shade and irrigate with 45 litres of water once in four days for the young seedlings. Weeding to be done when required.
- Apply 3kg vermicompost in the first year, 5kg in the second year, 10kg in the third year and 15kg from the fourth year onwards.

Table 8 Products for use in pest and disease management

Banned/prohibited	Permitted
Synthetic chemical pesticides Nicotine formaldehyde and phenols for soil sterilization, methyl bromide and other chemical soil sterilization chemicals metaldehyde, mercurial seed dressings etc.	Mechanical traps, chromatic traps, plant-based repellents silicates propolis bentonite soft soap gelatine bio-dynamic preparations
Restricted	**Allowed only with council's certification/ approval**
Pheromones Plant and animal oils release of predators or parasites of insect pests viral, fungal and bacterial preparations sterilized insects sulphur copper salts permanganate of potash chlorine of lime soda light mineral oils *Azadirachta indica* *Derris* root (rotenone) diatomaceous earth *Pyrithrum cinerariaefolium* *Ryania spectosa* tobacco tea *Quassia amara* nematicides from natural sources, eg., *Tyestus*, etc.	Non-mercurial seed dressing traps containing prohibited insecticides diatomaceous earth winter tar oil wash slug killers based on aluminium sulphate metaldehyde tape (only on non-cropping areas) formaldehyde and phenols (for sterilization of equipments and structures only) (A withdrawal period of 8 weeks must be observed after the use of all these products)

- Raise cover crops such as *Pueraria phaseoloides Mimosa invisa* and *Calopogonium mucunoides* in the interspaces.

Maintenance of adult plantations

- Provide drip irrigation at the rate of 32 lit./palm/day with 4 emitters in laterite and sandy loam soil and 6 emitters in sandy soil during summer months.
- Recycle the waste biomass available in coconut plantations including leaves, bunch waste etc. by vermicomposting in coconut basins or in pits or in cement tanks using earthworm *Eudrilus* sp.
- Raise cover crops in the basins of palms and the perennial legume, *Glyricidia sepium* in the interspaces or in the border areas.
- Apply 15kg of vermicompost, 25kg of green manures, biofertilizers (100g each) of N fixers and phosphobacteria and 2kg coconut husk ash per palm per year.
- Bury husk in the interspaces in trenches of 2m wide and 0.5m deep between rows of palms for moisture conservation.
- Do not adopt control measures against pests unless it assumes serious proportions. Adopt biocontrol measures against pests and diseases

Mixed farming in coconut garden

- Raise fodder crops such as guinea grass or hybrid napier and mulberry in the interspace.
- Plant black pepper and train on the stem of coconut. Grow other compatible crops
- Maintain milch cows (5 Nos/ha) and establish biogas plants using cow dung produced in the system to generate gas for cooking and lighting purpose.
- Integrate enterprises such as poultry, rabbitry, pisciculture and sericulture to enhance income from the system.
- Recycle cattle manure, urine, biogas slurry and wastes from poultry, rabbitry and sericulture as manure to coconut and fodder crops.

9. Summary

There is worldwide awareness for adopting organic agriculture due to the deterioration of soil health and increased environmental pollution caused by indiscriminate use of chemicals and off farm inputs. The basic concept of organic farming involves the use of on farm organic sources to meet the nutrient requirement of crops dispensing with the use of chemicals and off farm inputs. Enormous potential exist for organic farming in coconut due to the availability of large quantities of waste biomass in coconut plantation itself. Adoption of appropriate techniques for recycling of waste biomass, effective utilization of nitrogen fixing potential of legumes and biofertilizers can go a long way to achieve sustainable production in coconut in an eco-friendly manner. Integrated farming with diversity of crops and animal enterprises as well as on farm recycling in coconut holding may add further dimension for soil fertility management to obtain consistently high production of coconut without the use of chemical inputs.

***