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Technological Advances in Organic Farming of Plantation Crops

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INTRODUCTION

A range of plantation crops including tea, coffee, rubber, coconut, oil palm, cashew, arecanut, cocoa and spices are cultivated in the humid tropics and tropical belts of the country extending throughout the peninsular India comprising of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, West Bengal, Goa, parts of Maharashtra, and the north-eastern region. They are cultivated in wide range of soils ranging from sandy, sandy loam and laterite. These crops occupy an area of about six million hectares which is about 3.4% in the gross cropped area. Plantation crops serve a variety of human needs such as food, oil, industrial raw materials, beverages and confectionary items. Coconut, arecanut, cashew and cocoa are the major small holder's plantation crops cultivated in India. The major socio-economic features in which these crops are cultivated include predominance of small and marginal holdings, medium to resource poor farm environment, less marketable surplus and marketed surplus.

Plantation Crop Based Cropping/Farming Systems

Cropping/farming systems by raising compatible subsidiary crops and/or integrating with livestock enabled to increase the productivity and net returns from unit area of coconut and arecanut plantations. Farm resources like land, labour, sunlight, water and nutrients were effectively utilized in the system and higher productivity was achieved as a result of synergistic interaction among the crop and crop-livestock components. Crop diversity involving a number of annual, biennial or perennial crops as inter/mixed crops in perennial stands of coconut and arecanut promoted the productivity and sustainability of the system.

The beneficial effects were also reflected on non-monitory inputs such as enhanced soil fertility status, microbial activity and nutrient transformations which were conducive for sustainable crop productivity.

The coconut farmers in India, especially in the homestead gardens of Kerala state are accustomed to grow a variety of crops in the interspaces of coconut palms to meet this food, fodder, fuel, wood and timber requirements in addition to generating supplementary income. Many of this traditional cropping system mimic mature and create well-established agro-ecosystems with minimum dependency on external inputs to sustain production. The scientific research resulted in the development of a number of highly productive economically viable cropping system models. Coconut based High Density Multispecies Cropping Systems developed at CPCRI involves growing a diversity of crops at very high population per unit area to maximize production and economic returns. The inter crops include black pepper, clove, banana and pineapple (Bavappa *et al.*, 1986). Mixed farming system involves cultivation of forage grasses as feed for dairy cows which are maintained in the system and recycling of wastes back to the system as a source of nutrients for coconut palm. This system is a typical example of utilization of soil–plant–animal relations in a man made agro-ecosystem (Maheswarappa *et al.*, 2000).

Need for Sustainable Organic Production Systems in Plantation Crops

The low level of adoption of management practices particularly chemical fertilizers by the farming community is the major factor responsible for low productivity in farmers' gardens particularly in small holders' plantation crop like coconut. Resource constraints is also leading to low level of adoption of technologies. The soil conditions and climatic factors including high level of precipitation and high temperature result in the loss of major portion of chemical fertilizers applied to the soil by leaching and de-nitrification resulting in low nutrient use efficiency in tropical soils. Soil degradation is taking place due to the continuous application of chemical fertilizers without adequate organic inputs and the farming practices which leads to over exploitation of natural resources. Pollution of water bodies is taking place as a result of leaching of chemicals from the agricultural systems. Reduced crop and soil health because of poor organic matter content and micro-nutrient deficiencies are the other constraints in the production systems experienced now. All these factors underline the need for soil and plant health management to achieve sustainable production protecting the environment and safeguarding the natural resources. There is also a need to reduce the cost of inputs to enhance competitiveness in the international market under the changing global scenario.

Plantation Crops – Amenability to Organic Farming

Plantation crops are highly amenable to organic farming as they produce large quantities of waste biomass which, if recycled, can meet the nutrient demand of the crops to a great extent. The availability of waste biomass from a well managed coconut garden with 175 trees/ha has been estimated to be 14 tonnes/ha/yr in the form of leaves, spathe, bunch waste and husk. A considerable portion of husk is used for extraction of coir fibre. Coir dust, the by-product of coir processing factories, is usually dumped without any use often causing environmental pollution. It has been estimated that 7.5 million tonnes of coir dust is available in the country from the various coir defibering units. The total availability of waste biomass from 1.93 million hectare of coconut plantation in the country has been estimated as 14.36 million tonnes annually (Table 3.1). The natural decomposition of these wastes and the nutrient release are very slow due to 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.

Table 3.1. Availability of on-farm wastes/ by products in plantation sector in India

Crop/Crop waste	*Quantity available*
Coconut (excluding coir pith)*	14.36 million tonnes
Areca leaves	0.13 million tonnes
Areca rachis	0.08 million tonnes
Areca husk	0.22 million tonnes
Cocoa shed leaves	360.03 tonnes
Cocoa pruning	12056.33 tonnes
Cocoa pod husk	32900 tonnes
Coir pith	7.5 million tonnes
Coffee husk	0.18 million tonnes
Tea waste	0.22 million tonnes

* includes spadices, bunch wastes, sheath, inflorescences and husks

The organic wastes can be directly utilized as mulch or converted into composts 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.

On-farm Waste Recycling through Vermi-composting

When the organic wastes available from a plantation are recycled, it can supply the major portion of nitrogen and a part of other nutrients required by the palms. Studies conducted at CPCRI, Kasaragod have revealed that coconut plantation wastes could be effectively converted into rich vermi-compost using a local species of epigeic earthworm belonging to *Eudrilus* sp. The *Eudrilus* sp. was located from a heap of coconut palm wastes at CPCRI farm. Among the local earthworms tested for their ability to multiply and produce vermi-compost from coconut palm wastes, this strain of *Eudrilus* was the best and hence more studies were conducted. The local strain of *Eudrilus* is different from *Eudrilus eugeniae*, the African night crawler, which has its origin in tropical and subtropical Africa. The strain of *Eudrilus* located at Kasaragod differs from the African strain in its colour, vigour, behaviour, cocoon colour and reproductive rate on coconut wastes. The local strain is more darkly pigmented and vigorous and the cocoon case is thick and dark. Interestingly, it is also capable of burrowing in coarse soils such as sandy loam and in soft bedding materials. It is also capable of actively feeding on soil and digested soil in the form of pellets is deposited around burrow holes.

The low cost vermi-composting technology developed at CPCRI enables production of high quality organic manure from coconut leaves in a period of 60–75 days (Prabhu *et al.*, 1998; Thomas *et al.*, 2001). Vermi-composting can be done ideally in permanent cement or brick tanks constructed under shaded conditions to maintain appropriate quantity of substrate, optimum moisture and temperature which are necessary for efficient vermi-composting. This will also provide an opportunity to provide protection for the worms from predators like rodents, ants, birds and wild boars. The weathered wastes obtained during rainy seasons are preferred. These organic wastes are to be treated with cow dung at the rate of 10% by weight in the form of slurry and must be allowed to undergo a preliminary decomposition for about 2-3 weeks. The earthworms at the rate of 1000 worms per tonne of coconut leaves are to be introduced. 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. In about 60–75 days compost will be ready, leaving behind only a portion of undecomposed material. Composting was

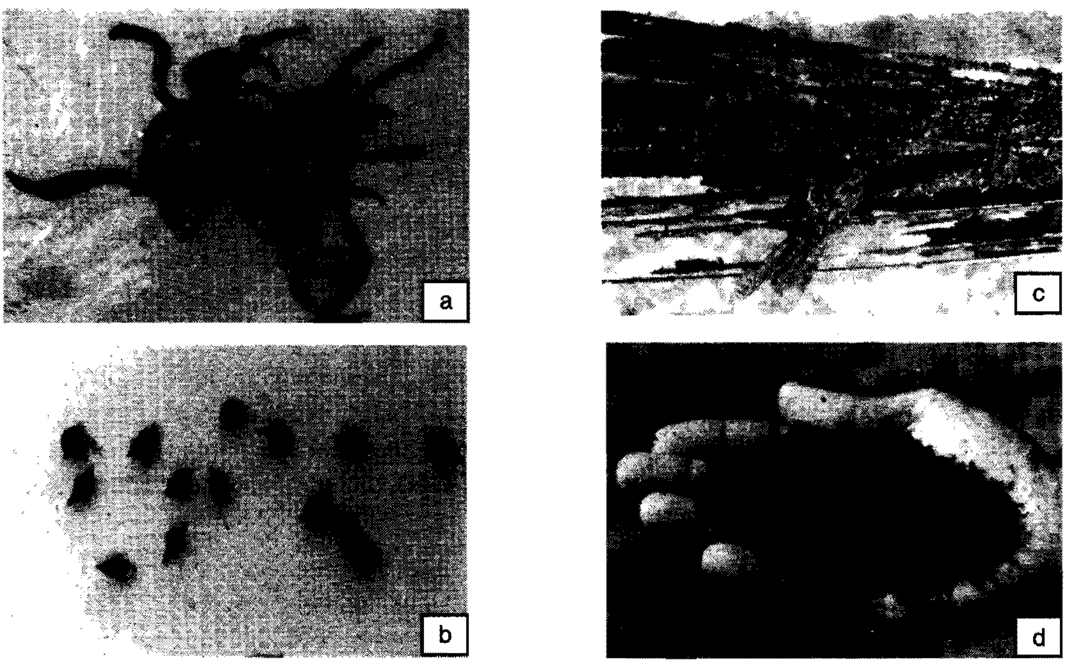


Fig. 3.1. Vermicomposting of coconut leaves: a. *Eudrilus* sp., b. Cocoons of *Eudrilus* sp., c. Coconut leaves undergoing composting, d. Vermicompost

faster in heaps and the earthworms were seen feeding and casting from all sides may be due to better aeration and exposure. On an average, 70% recovery of vermi-compost was obtained. The average nutrient composition of vermi-compost recovered was found to be 1.8% N, 0.2%P, 0.2% K, 17.84% organic carbon and C: N ratio of 9.95:1. The composted palm wastes also contained higher levels of micro nutrients such as Fe, Zn, Cu and Mn when compared to that of the untreated substrate. The same technology for vermi-composting was also tested in large pits taken in the inter spaces of four coconut palms in sandy loam and coastal sandy soils and was found to work well. When composting is done in the field itself, lot of labour required for transportation of the biomass and compost can be saved. This technology is also suitable for plantations with very limited irrigation facilities, as only a limited number of pits or trenches need to be watered.

The C : N ratio of the organic matter ingested by the earthworm decreases and bound nutrients are converted into easily available forms during the vermi-composting process. A small portion of this digested organic matter is absorbed by the earthworm and the left over, which is relatively stable humus-like organic matter is egested in the form of pellets or granules, frequently referred to as vermi-castings. The gut passage of organic matter results in enhanced availability of nutrients, increased counts of microbes and enrichment with a number of bio-active compounds. Two types of active nitrogen fixing bacteria not commonly isolated from soils have also been found regularly associated with vermi-casts. Thus, vermi-compost increases soil fertility through addition of plant nutrients, growth hormones, increased level of soil enzymes and important micro-organisms as they are rich in microbial diversity, population and activity.

The changes in the occurrence and population of 15 types of beneficial micro organisms were studied during different stages of vermi-composting. There was significant variation in the population levels of different groups of micro-organisms in the substrate, during the composting process in the gut of earthworm and vermi-compost. The levels of fungi, asymbiotic nitrogen fixers, nitrosomonos, nitrobacter, ammonifiers, fluorescent pseudomonas, phosphate solubilizers and silicate oxidisers were significantly high in vermi-compost when compared to that of substrate and gut of earthworm.

Coir pith, a byproduct obtained after extraction of coir fibres from husk, accumulates as waste around the coir fiber extraction units causing environmental hazard. Though coir pith has many beneficial attributes such as high moisture holding capacity and plant nutrient content, the use of raw coir pith in crop production is not recommended as manure due to the high C: N ratio of more than 100:1.

Research efforts on the utilization of this valuable resource indicated that it can be converted into compost either through the use of local species of *Eudrilus* or through microbial degradation, and the final product can be used to improve soil physical properties and moisture holding capacity to a great extent (Thomas *et al.*, 2001). The composted biomass was found to be of superior quality with respect to content of major and micronutrients and plant beneficial micro-organisms particularly the bacteria involved in nutrient transformation and growth promotion.

Co-composting coir pith with solid poultry manure with and without lime and rock phosphate amendment revealed that the composting process facilitated by poultry manure amendment brought about bioconversion of coir pith to a final product in 45 days and the final product possessed physico-chemical characteristics required for quality organic manure. C : N ratio, which is considered as a maturity index of composting process, got reduced during the composting process to 21.42. The composted coir pith can be used as manure in coconut plantations and can increase the capability of soils to store moisture and nutrients.

Fallen leaves, bunch wastes husk are the major source of organic wastes in arecanut garden. About 0.1317 million tonnes of dried areca leaves, 0.0832 million tonnes of dried arecanut bunch waste and 0.2224 million tonnes of dry arecanut husk are estimated to be available annually in India. The non-marketed produce in arecanut garden viz., areca-shed leaves, sheath, husk and arecanut bunch waste supplies approximately 94.6g, 10.0g and 109.63g of N, P_2O_5 and K_2O, respectively per palm per year. These available arecanut wastes have potential to supply 5,260, 1,337 and 6,230 tonnes of N, P and K, respectively to the agricultural system annually. Cocoa is grown as mixed crop in coconut and arecanut plantations and crop is cultivated in an area of 30,000 ha in the country. Cocoa wastes could contribute 540, 72 and 1,244 tonnes of N, P and K per year, respectively.

Crop Residue Availability and Recycling in Cropping/Farming System

The coconut based High Density Multi Spices Cropping System comprising clove, black pepper, banana and pineapple yielded 23.51 t/ha/year of recyclable biomass from the system. The extent of nutrient recycling from biomass was estimated to be 130 kg N/ha, 8.5 kg P/ha and 121 kg K/ha (Palaniswami *et al.*, 2007).

Vermi-composting trials undertaken in large cement tanks to evaluate the effect of mixing crop residues of component crops with coconut leaves on vermi-compost production by *Eudrilus* sp. revealed that recovery of compost was 60–65 % in the mixture of coconut leaves + banana pseudostem and leaves, coconut leaves + glyricidia leaves (3:1 proportion) compared to 70% when coconut leaves alone was tested. (Table 3.2). The C: N ratio of vermicompost produced varied from 12.27–13.20.

Table 3.2. Recycling of waste biomass of coconut based cropping system by vermicomposting

Treatments	*Recovery (%)*	*Organic carbon (%)*	*Nitrogen (%)*	*C:N ratio*	*Phosphorus (%)*	*Potassium (%)*
Coconut leaves + banana (3: 1) pseudostem	60	19.96	1.51	12.27	0.24	0.29
Coconut leaves + Glyricidia (3:1)	65	15.84	1.23	13.20	0.26	0.48
Coconut leaves alone	70	17.15	1.34	12.49	0.22	0.41

The coconut based mixed farming system comprising of dairy, poultry and silk worm rearing contributed sizable quantities of biomass viz. 14 tonnes of cow dung, 295 kg of poultry bedding materials and droppings, 12 kg of silk worm waste (all on dry weight basis) and 50,000 litres of cowshed washings. This waste biomass on recycling could meet 74 % N, entire quantity of P, and 82 % of K requirement of both coconut and grass (Thomas and Palaniswami, 2005).

The recyclable biomass production from sole arecanut was estimated at 8.7t ha^{-1} and it can be considerably increased to 14.3 tonnes ha^{-1} with adoption of High Density Multi Spices Cropping System (Bavappa *et al.*, 1986). Though the quantity of recyclable biomass is reduced after 15 years of adoption of Arecanut Based Cropping System, still there is scope for efficient and economical recycling (Bhat and Sujatha, 2007). Recyclable biomass produced from different component crops in arecanut based cropping system varied between 8,724–10,354 kg ha^{-1} $year^{-1}$. The recyclable biomass can be converted into vermi-compost with 82–87% recovery. The estimated nutrient content in vermicompost was 1.71% N, 0.21% P and 0.43% K (Table 3.3).

Table 3.3. Nutrient composition of vermicompost made out of cocoa and arecanut leaves

Nutrients	*Cocoa*		*Arecanut*	
	Dried leaves	*Vermi-compost*	*Dried leaves*	*Vermi-compost*
OC (%)	47.10	24.4	OC(%)	47.10
N(%)	1.27	1.65	N(%)	1.27
P(%)	0.17	0.19	P(%)	0.17
K(%)	0.27	0.32	K(%)	0.27
C:N ratio	37.00	14.78	C:N ratio	37.00
Cu(ppm)	32.66	83.60	Cu(ppm)	32.66
Fe(ppm)	1157.41	2593.0	Fe(ppm)	1157.41
Zn(ppm)	228.39	367.7	Zn(ppm)	228.39
Mn(ppm)	363.1	679.84	Mn(ppm)	363.1
pH		7.5	pH	

Vermi-wash for Growth Promotion and Quality Produce

Another important product of vermi-composting technology is the vermiwash, which is rich in nutrients in readily available form, plant growth promoting hormones, beneficial micro-organisms and can be used for improving the productivity of crops. Vermi-wash has been found to be effective as foliar spray for growth promotion and bio suppression of pathogens in crop plants. All the physiologically active water soluble components of vermi-compost such as humic acids, plant growth regulators, amino acids, vitamins, micro-nutrients and microbial cells are extracted in water and is known as vermi-wash. The water soluble components from vermi-compost may be collected by passing water slowly through the worm beds or by simple suspension of vermicompost in water. This is used for foliar applications as such or after sufficiently diluting, based on the need. Vegetables and ornamental plants have been found to respond very well to this treatment.

Vermi-wash produced from actively vermi-composting substrates of coconut leaf + cow dung by *Eudrilus* sp had (Table 4.4) an alkaline pH, contained major and minor nutrients, growth hormones, humic acid and plant beneficial bacteria (Murali Gopal *et al.*, 2008). Application of appropriately diluted coconut leaf vermi-wash (CLV) increased germination and seedling vigour index of cowpea and paddy seeds in laboratory bioassays. Field trials with cowpea, maize and bhendi in the Institute farm showed its capacity to enhance the biomass and yield of the crops accompanied by higher soil microbial activities. Field trials were conducted in farmers' plots with bitter gourd, cowpea, amaranthus, and chillies. Observations indicated that application of vermi-wash had resulted in yield of crops on par or slightly lower than the plots that received regular fertilizer inputs (Murali Gopal *et al.*, 2008). However, the farmers listed many other important points viz. healthy plant and root hair growth, lesser pest and disease damage, larger and deep leaf colours, longer ability of plants to stay without wilting in field as well as longer time of remaining fresh in case of amaranthus after harvesting, more freshness of fruits etc.

Table 3.4. Characteristics of Vermi-wash from coconut leaf vermi-compost

Nutrients	*Conc. (ppm)*	*Biochemical constituents*	*Conc. (µg/ml)*	*Micro-organisms*	*Population (cfu/ml)*
N	2.8	Total sugars	61.6–111.2	Bacteria	2×10^3
P	10.2	Reducing sugars	41.9–88.4	Fungi	85
K	205	Free amino acids	20.8–32.3	Actinomycetes	9×10^3
Ca	37.9	Proteins	615–890	Phosphate solublilizers	25×10^2
Mg	6.5	IAA	0.52–1.15	N_2 fixers	15
Fe	Traces	Gibberellic acid	0.23–1.61	Fluorescent pseudomonads	8×10^2
Cu	Traces	Total pheno	10.2–14.8		
Zn	0.07	pH	7.6–8.9		
Mn	0.17				

Utilization of Efficient Legume-Rhizobium/Bradyrhizobium N_2 Fixing Systems

Nitrogen fixing legumes possessing symbiotic association with efficient *Rhizobium/ Bradyrhizobium* strains can be important inputs in organic cultivation of coconut (Fig 3.2). 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 (Thomas and Shantaram, 1993). It involves cultivation of leguminous creepers such as *Pueraria phaseoloides, Mimosa invisa* and *Calopogonium mucunoides* in coconut basins during the monsoon period from June—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 3.5).

Fig. 3.2. Basin management of coconut with *Calopogonium mucunoides*

Table 3.5. Biomass and N contribution by green manure legumes in coconut basins

Legume species	*Laterite soil*		*Sandy soil*	
	Biomass(kg/basin)	*Nitrogen(g/basin)*	*Biomass(kg/basin)*	*Nitrogen(g/basin)*
Calapogonium mucunoides	27.21	186.53	14.71	102.61
Mimosa invisa	24.67	197.55	17.00	153.19
Pueraria phaseoloides	28.45	196.19	19.43	121.29

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 crops in coconut plantation in littoral sandy soil was standardized (Subramaniam *et al.*, 2000). The highest fresh biomass yield of 8t/ha/year was obtained in the treatment with three rows of *Glyricidia* and three prunings per year (Table 3.6). The contribution of major nutrients through the loppings of *Glyricidia* was about 77.6 kg N, 5.7 kg P and 26.8 kg K per ha annually. The cultivation and incorporation of green leaves of *Glyricidia* helps in improvement in physical, chemical and biological properties of soil which are beneficial for the plant growth.

Table 3.6. Biomass yield and nutrient contribution of *Glyricidia* alley cropped in coconut gardens (kg/ha)

Glyricidia treatment	*Fresh biomass*	*Dry biomass*	*N*	*P*	*K*
2 rows, 3 prunings	6194	1816	61.5	4.6	20.4
2 rows, 3 prunings	5479	1594	54.8	4.0	18.4
3 rows, 3 prunings	7970	2296	77.6	5.7	26.8
3 rows, 4 prunings	7211	2011	69.5	5.1	24.0

Living Soil as Basis for Organic Farming

Living soil concept is basic to organic farming. The role of soil flora and fauna is well-recognized in this system of production as the prime drivers for various processes resulting in enhanced physical, chemical and biological health of soil. The inadequacy of nutrient and energy sources in the tropical soils is the limiting factor for the low biological activity and dormancy of large number of beneficial micro-organisms in soil. The concept of organic farming dwells on the realization of the biological potential of soil microbes and their capability to support the production process if the soils are fed with sufficient organic matter. The focus in organic farming is on development and application of innovative agro-technologies based on soil biodiversity to enhance the natural nutrient cycles and utilization of specific soil-plant-microbial associations in managing the soil in organic production. More soil biodiversity leads to stability and sustainability of production systems. Biological systems of regulation promoted by the soil microbes should function at the highest level to achieve closed nutrient cycles with less nutrient losses.

Microbial Resources and their Utilization

Biofertilizer formulations containing living cells of beneficial micro-organisms multiplied in suitable carrier can form low cost ecofriendly inputs for organic crop production. A range of micro-organisms possessing beneficial traits such as biological nitrogen fixation, phosphorus mobilization and production of plant growth promoting substances have been found to be closely associated with coconut palms (Thomas *et al.*,1991).

The diazotrophic bacteria isolated from coconut roots include different species of *Azospirillum*, *Herbaspirillum* sp., *Azoarcus* sp., *Burkholderia* sp., *Arthrobacter* sp., *Pseudomonas* sp. and *Bacillus* sp. (Prabhu and Thomas, 1999 Thomas *et al.*, 2001), *Beijerinckia indica* was the predominant asymbiotic N_2 fixer in coconut soils (Table 3.7) (Thomas *et al.*, 1985). Phosphate solubilizing microbes of coconut soil include *Pseudomonas* sp., *Bacillus* sp. and *Micrococcus* sp. (Thomas and Shantaram,1986). Efficient strains of nitrogen fixing bacteria and phosphate solubilisers were used for preparation of biofertilizers employing locally available materials such as vermicompost and coir pith as carrier materials. Inoculation trials indicated that the biofertilizers were effective in enhancing the vigour of coconut seedlings raised in polybags with 1:1 coir pith - soil mixture as substrate.

Table 3.7. Diversity of beneficial microbes associated with coconut palm

Type of association	*Group of organisms*	*Important genera*	*Beneficial traits*
Symbiotic	Arbuscular mycorrhizae	*Glomus* spp.	• Uptake of immobile elements
		Gigaspora spp.	• Uptake of water under moisture stress condition
		Acaulospora spp.	• Biosuppression of root pathogen
		Sclerocystis spp.	
		Scutellospora spp.	
Associative symbiotic	Diazotrophs	*Azospirillum* spp.	• Fixation of atmospheric N_2
		Herbaspirillum spp.	• Production of plant growth promoting substances (PGPS)
		Azoarcus spp.	
		Burkholderia spp.	
		Arthrobacter spp.	
		Xanthobacter spp.	
		Pseudomonas spp.	
Endophytic	Plant Growth Promoting	*Bacillus* spp.	• Production of plant growth promoting substances
	Rhizobacteria (PGPR)	*Pseudomonas* spp.	• Biosuppression
Rhizospheric association	Diazotrophs	*Beijerinckia* spp.	• Fixation of atmospheric N_2
		Azospirillum spp	• Production of PGPS
	Phosphate mobilisers Fungi	*Aspergillus* spp.	• Production of polysaccharides
		Penicillium spp.	helping in soil aggregation
	Bacteria	*Bacillus* spp.	• Solubilisation of insoluble
		Micrococcus spp.	phosphates
		Pseudomonas spp.	• Production of PGPS

Recent studies at CPCRI resulted in the isolation of several strains of fluorescent pseudomonads from rhizosphere of coconut and cocoa with plant growth promotion properties (Litty Thomas, 2009; Priya George *et al.*, 2009). Screening of the isolates revealed that 90% of the isolates from coconut exhibited phosphate solubilizing capability, siderophore production and ammonification. IAA production and ACC deaminase activity was noticed in 85% of the isolates. Five percent of the isolates produced HCN and 2% of the isolates showed growth in N-free media. Antagonistic activity against pathogens of coconut such as *Ganoderma sp.* (causing basal stem rot disease) and *Thielaviopsis paradoxa* (causing stem bleeding disease) was shown by 8–16% of the PGPR isolates. Enormous possibilities exist for utilization of these efficient PGPRs for development of bioformulations and their applications in crop production.

Symbiotic associations with coconut roots is formed by several species of AM fungi belonging to five genera and the association provides benefit to the host plants in terms of crop nutrition, disease suppression and increased growth and yield of crops.

Soil Health Benefits Under Organic Farming

Soil health benefits due to organic farming is evident from the results obtained in the coconut based mixed farming system involving cultivation of fodder grass in the interspaces of coconut palms and integration of animal husbandry involving dairy, poultry and pisiculture as components to enhance the income from coconut gardens. The system was maintained with three treatments including 100% organics, 100% inorganic and 50% organic + 50% inorganic. The population density of soil microbial groups and function specific micro-organisms of beneficial micro-organisms were very high in the organic treatment when compared to the other treatments. The increase in the population of fungi was considerably high in 100% organic treatment compared to the other treatments (Table 3.8). Proliferation of micro-organisms was remarkably low in the treatment that received 100% chemical fertilizer.

Table 3.8. Microbial distribution in organic, inorganic and integrated nutrient management in coconut - fodder grass system

Treatments	*Bacteria* *(10^6 cfu/g soil)*		*Fungi* *(10^3 cfu/g soil,)*		*Actinomycetes* *(10^6 cfu/g soil)*	
	Coconut	*Interspace*	*Coconut*	*Interspace*	*Coconut*	*Interspace*
Monocrop + RF	13.45	10.00	6.86	4.16	9.62	6.16
MF + 50% organic + 50% inorganics	18.22	21.64	6.6	7.23	7.83	8.35
MF + 100% organics	23.17	29.22	18.16	19.31	11.33	14.26
MF + 100% inorganics	11.76	14.66	7.12	8.35	7	12.94

RF – Recommended fertilizers dose; MF – Mixed farming

Increase in microbial biomass and activities of soil enzymes (phosphatase and dehydrogenase) indicated that the soil biological activity was more in the farming system under organic system of cultivation than under inorganic or integrated treatment (Table 3.9). Microbial biomass was significantly high in the system where organic recycling was practiced. The microbial biomass is considered among the most labile pools of organic matter and thus, serves as the reservoir of plant nutrients.

Phosphatase activity relates to hydrolyzing P compounds and liberating P from insoluble sources for absorption by plants. The dehydrogenase activity was remarkably high in organic treatment which indicated higher level of microbial oxidative activity.

Table 3.9. Microbial biomass and enzyme activities in coconut based mixed farming systems

Microbial parameters	Microbial biomass (μg C g^{-1} soil)		Phosphatase (μg p-nitrophenol g^{-1} soil h^{-1})		Dehydrogenase (μg formazon g^{-1} soil h^{-1})	
Treatment/crop	Coconut	Interspace	Coconut	Interspace	Coconut	interspace
Monocrop	190.79	153.56	45.07	22.49	7.53	5.34
50% organic	213.51	264.26	49.87	31.79	10.57	15.77
100% organic	292.04	312.18	62.15	51.98	16.66	22.99
100% inorganic	142.07	193.03	32.97	19.92	5.73	12.46
CD (P = 0.05)	11.19	4.85	2.69			

The quality of an agricultural soil is a measure of its capacity to sustain crop productivity while preserving environmental quality. Organic farming had positive contribution to soil functions to sustain crop growth and productivity. The augmented microbial build up and activities, biochemical changes and nutrient transformations mediated by soil micro-flora and microbial interactions enabled to achieve sustainability of the system.

CROP YIELD REALISED UNDER ORGANIC FARMING

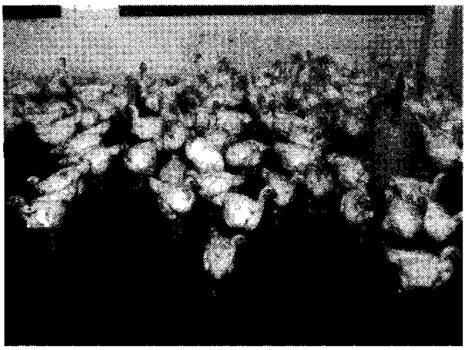
Organic cultivation of coconut was found feasible with integrated treatments utilizing organic and bioinputs including recycling of waste biomass by vermicomposting, *in situ* cultivation and incorporation of leguminous cover crops and biofertilizers of *Azospirillum* and *Bacillus*. In a field trial conducted in an adult coconut plantation, the yield obtained with West Coast Tall cultivar of coconut under organic cultivation was 83 nuts/palm/year while in Dwarf X Tall hybrid (Chowghat Orange Dwarf X West Coast Tall), the yield was 93 nuts/palm/year.

Coconut based farming system with inter cropping of fodder grass in the inter-spaces of coconut with dairy and poultry as components (Fig. 3.3) was maintained with organic inputs including the recycling of cowshed wastes and vermi-composting of the biomass generated in the system. The yield of coconut in the organic cultivation was 108 nuts/palm/year and fodder yield was 106 t/ha/year. The system was highly remunerative with net return of Rs. 1,37,164/ha/year achieving economic and environmental advantages under organic farming.

Field experiments conducted under the All India Coordinated Research Project on Palms (AICRP, 2000) in different coconut growing tracts of the country had organic treatments such as composted coir pith to supply 100% N and neem cake + bone meal + ash. The yield under organic cultivation ranged from 80 nuts/palm/year to 145 nuts/palm/year in different locations (Fig. 3.4). This data revealed that economically viable coconut cultivation is feasible when palms are managed with organic inputs alone and organic cultivation of coconut is a viable proposition for profitable cultivation of coconut in a sustainable environment friendly manner.

Fodder grass intercropping

Dairy unit



Poultry unit

Fig. 3.3. Coconut based farming system at CPCRI, Kasaragod

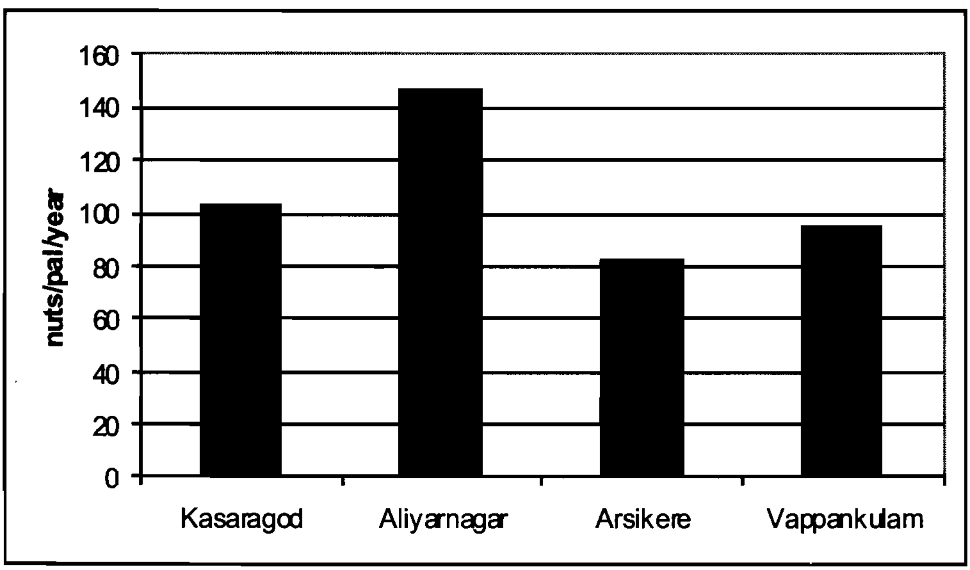


Fig. 3.4. Effect of organics on coconut yield

Under organic farming with application of vermicompost to supply 100 % of recommended N in arecanut the yield obtained was 1.70 kg dry nut (chali)/palm/year which indicated that arecanut crop can be cultivated with organic inputs to realize higher economic yield.

CONCLUSION

There have been significant advancements in the development of agro-technologies based on the principles of organic farming in plantation crops. The growth habit and planting methods of crops like coconut and arecanut make it highly amenable for organic farming through the low cost technologies based on the local resources. These agro-technologies integrate ecological principles into intensification process and ensure that plant nutrients are in constant and close cycling within the soil and plant compartments. They rely on wide variety of biological strategies adopted by the soil systems and are governed by the soil microbial dynamics.

Technologies are available for production of sufficient quantities of organic matter, efficient recycling and generation of high quality compost and growth promoting liquid formulations and utilization of microbes to supply the plant nutrients without any ecological damage as is the case with chemical agriculture. Enhancement of biodiversity is the primary principle used to evoke self-regulation and sustainability of the agro-ecosystems. When biodiversity is restored, a number of complex interactions between soil, soil organisms, plants and animals are established, giving stability to the system to form viable and sustainable organic production systems.

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