

Bioresource Management for Organic Farming in Coconut under Coastal Ecosystem

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The coconut palm is predominantly grown in nutrient poor soils under coastal ecosystem by the small holders with low use of external inputs. Biological strategies based on optimum use of locally available resources offer opportunities to achieve sustainability in production of the palm. The perennial nature of the palm, its growth habit, planting methods, production of large quantity of organic wastes throughout the year and association of rich diversity of beneficial microbes are the factors in favour of organic and biomanagement of the coconut palm. The low cost vermicomposting technology standardized at CPCRI enable bioconversion of lignocellulosic waste biomass from coconut palms into rich organic manure using local strain of epigeic earthworm belonging to the *Eudrilus* sp. Bioconversion of coir pith, a lignocellulosic waste biomass from coir processing industry to acceptable organic manure has become possible with the use of biopolymer degrading fungi. Basin management with efficient N₂ fixing leguminous cover crops such as *Pueraria phaseoloides*, *Mimosa invisa* and *Calopogonium mucunoides* enable generation of significant quantity of organic biomass and nitrogen at the site of need itself. Alley cropping of *Glyricidia* and incorporation of nitrogen rich organic biomass enabled the effective management of coconut gardens in littoral sandy soil. Biofertilizers of nitrogen fixing bacteria and P-mobilisers with the capabilities of production of plant growth promoting substances are valuable inputs for crop management.

(Key words : Coconut, Bioresource management, Organic farming, Vermicomposting)

The coconut palm (*Cocos nucifera* L.), a small holders plantation crop, is predominantly grown under coastal ecosystem in the western and eastern coast of the country. The perennial palm, which is known as "Kalpavriksha" or "tree of life", due to its multifarious uses, has an important role in the economy of the country as it sustains the livelihood of 10 million people in the coastal region, who are directly or indirectly involved in cultivation, processing and trade. The great majority of small holders manage their gardens with low use of external inputs, resulting in unsustainable productivity. Biological strategies based on optimum use of locally available resources offer opportunities to maximize soil productivity and minimize the cost of production.

The coconut palm, being perennial in nature, requires adequate nutrition throughout the growing period due to the continuous flowering and bearing habit. A holistic approach to resource oriented management practices is essential to achieve sustainability in production. Increasing realization of the detrimental effects of exclusive use of chemical fertilizers and consistently growing consumer

demand and non-sustainable productivity have enabled to refocus attention on organic culture as a benign alternative. In organic farming, the nutrient requirement of the crops has to be met through organic and bioresources. 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. Only soils with high diversity of flora and fauna can continuously support the growth of healthy crops and are termed as living soils, which are considered as basis of organic farming.

Relevance of organic farming in coconut

The coconut palm, in general, is grown on coastal soils of low nutrient availability. The palm removes nutrients from limited volume of soil and replenishment of nutrients is highly essential to maintain the fertility of the soil. 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 (Pillai and Davis, 1963). Hence, there is a continuous nutrient demand for the crop to replenish the nutrients removed by way of export to above ground parts. Low productivity of the crop in

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the vast majority of coconut gardens is primarily due to the inadequacy of nutrient inputs by resource poor farmers. In this context, low cost organic farming technologies assume particular significance in the cultivation of the crop to develop production systems that are agriculturally sustainable, economically viable and environmentally sound.

The palm is one of the highly amenable crops for organic cultivation. Being a perennial crop the palm produces huge quantities of organic wastes throughout the year. The availability of organic recyclable biomass from a hectare of well managed coconut garden was estimated to be about 14-16 tonnes annually in the form of leaves, spathe, bunch waste and husk (Biddappa *et al.*, 1996). Additional quantity of waste biomass is available from the inter and mixed crops which forms the components of the coconut based cropping and farming systems. The availability of recyclable biomass from a hectare of coconut based high density multispecies cropping system has been estimated to be 20-24 t ha⁻¹ annually (CPCRI, 2003). Recycling of these residues in the plantation itself will help to meet the major nutrient demand of the crops.

Vermicomposting for recycling of coconut plantation wastes

The coconut plantation wastes, which are lignocellulosic in nature with higher lignin content, could be effectively converted into rich vermicompost using an epigeic earthworm or compost worm belonging to the *Eudrilus* sp. obtained from decomposing coconut waste heaps (Prabhu *et al.*, 1998, Thomas *et al.*, 2001). A low cost technology has been standardized for converting the weathered coconut leaves to acceptable organic manure with a C:N ratio of 9.95 with 70% recovery. The composting can be done in cement tanks, basins, heaps or large pits taken in the interspace of four coconut palms. The organic manure has a nutrient composition of 1.2 - 1.8% N, 0.1-0.2% P and 0.2-0.4% K. The vermicompost obtained from coconut leaves had beneficial attributes such as higher population of beneficial microbes, presence of plant growth promoting substances and humic acids. *In situ* vermicomposting in coconut plantations by heap or trench method enabled production of quality manure at the site of need at a lower cost. Nucleus culture of the local *Eudrilus* sp. is capable of composting coconut plantation wastes being supplied from CPCRI to the farmers. These worms have fast multiplication rate in a 1:1 mixture of cowdung and decayed leaves. Experiments conducted on polybag

raised coconut seedlings have shown that vermicompost at 20 percent level enhance the seedling growth and vigour. The results of the field experiments involving vermicompost application on adult coconut palms are indicative of the beneficial impact of vermicompost to enhance the productivity of palms.

Composting of lignin rich biomass using microbial cultures

Coir pith, a byproduct obtained after extraction of coir fibers from husk, accumulate as waste around the coir fiber extraction units causing environmental hazard. Coir pith, which is available at 7.5 million tonnes annually from different coir processing factories, is acidic in nature, and has low bulk density and high porosity. 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 a manure due to the high C:N ratio of more than 100 :1. Research efforts on the utilization of this resource indicated that biopolymer degrading microorganisms can bring about decomposition of the lignocellulosic biomass to produce acceptable organic manure suitable for application as a nutrient source for crops. The technology utilizing basidiomycetous fungus, *Pleurotus* *so/or* *caju* with the amendment of 0.5% urea has been reported for production of organic manure (Nagarajan *et al.*, 1989).

Studies at CPCRI on biopolymer degrading microorganisms involved in the natural decomposition of coconut wastes under field conditions resulted in the isolation of a number of fungal strains with high degradative capabilities as evidenced by production of ligninolytic and cellulolytic enzymes on lignin rich biomass. Among them, *Lepista* sp., *Lentinus squarrosulus*, *Schizophyllum commune*, *Marasmiellus troyanus* and *Trichoderma* sp. showed high degradation potential. The technology developed at CPCRI using microbial inoculants with amendments of lime, rock phosphate and legume biomass resulted in the production of quality compost with a C:N ratio of 15 : 1 within a period of 40-50 days (Thomas *et al.*, 2001). Enrichment of compost was done with biofertilizers of asymbiotic diazotroph, *Beijerinckia indica* and phosphate solubilising bacteria. The composted coir pith can be used as manure in coconut plantations and can increase the capability of soils to store moisture and nutrients.

The services of earthworms can also be utilized for composting of lignin and polyphenol rich coir pith, and a local strain of *Eudrilus* sp. has been found to be highly useful for this purpose. A technology for large scale composting of coir pith has been standardized at CPCRI, Kasaragod using this local earthworm. A granular vermicompost with 1.2% nitrogen and a C:N ratio of 16.7:1 can be obtained in two months (Thomas *et al.*, 2001).

Recycling of crop residues by mushroom cultivation

Utilization of lignocellulosic biomass for oyster mushroom cultivation and further conversion of the spent substrate to organic manure by composting or vermicomposting is a viable method for recycling of coconut palm wastes. A biological efficiency of conversion of 55-70% was obtained when coconut leaf stalk, bunch wastes or a combination of leaflets + bunch waste were used as substrates for oyster mushroom cultivation (Thomas *et al.*, 1998). Among the various species of *Pleurotus* tested, *P. sajor*, *caju*, *P. flabellatus* and *P. eous* were superior in sporophore production on coconut waste substrates. The spent substrate, when composted formed an acceptable organic manure with improved nutrient status and low C:N ratio. The composted, spent substrate had N content of 1.0 to 1.29%, P content of 0.08 to 0.13% compared to 0.45% N and 0.05% P in untreated substrate.

Basin management with leguminous cover crops

Leguminous cover crops, which are efficient in biological fixation of nitrogen, can contribute significant quantity of easily decomposable biomass and nutrients when grown as green manure crops in the basins and interspaces of coconut palm. The technique of basin management standardized at CPCRI involving cultivation of *Pueraria phaseoloides*, *Mimosa invisa* and *Calopogonium mucunoides* resulted in the generation of 15-28 kg of biomass and 102-175 g of nitrogen in the basin of a coconut palm during a growth period of 140-150 days (Thomas and Shantaram, 1984, 1993). These legumes have association with efficient strains of *Rhizobium* spp. and the nitrogen rich green matter is easily decomposable to release the bound nutrients for plant growth.

A field experiment conducted in a coconut plantation in an acidic laterite soil type revealed the feasibility of substituting upto 50% nitrogen with leguminous green manures (Thomas *et al.*, 1999). The cultivation of leguminous cover crops improved the microbiological properties of soil and yield of

coconut palm. Basin cultivation of leguminous crops was effective in the management of root (wilt) diseased palms showing improvement in the yield of the palm and marginal reduction in root (wilt) disease index. The cultivation of cowpea in the basins of coconut palms has also been shown to be a viable alternative crop that can be raised for green manures (Maheswarappa *et al.*, 2003). The cultivation and incorporation of green manure legumes can form an important component of the organic farming technology for sustainable agriculture.

Growing glyricidia as green manure crop under littoral sandy soil

The coconut growing coastal regions of the country have sandy soils which are characterized by poor physicochemical properties. Growing of perennial leguminous crop, *Glyricidia* has been found to be an effective method for the management of coconut gardens under littoral sandy soil. *Glyricidia sepium* when grown in three rows in between coconut palms at a spacing of 7.5 x 7.5 m yielded 7.9 t ha⁻¹ yr⁻¹ from three prunnings in February, June and October (Subramaniam *et al.*, 2000). Application of *Glyricidia* prunnings from interspace of one hectare of coconut garden could meet a major portion of nitrogen (90%), part of phosphorus (25%) and potassium (15%) requirement of coconut palm. Studies in Sri Lanka indicated that *Glyricidia* loppings when applied at the rate of 30 kg per palm could meet the total requirement of nitrogen and part of P and K and it can reduce the inorganic fertilizer inputs by 40% (Liyanage and Jayasundara, 1988).

Biofertilizers as low cost inputs

There is great potential for utilizing plant beneficial microorganisms as biofertilizers for sustainable coconut farming to increase the availability of nutrients and to enhance nutrient use efficiency. The coconut palm has association with unique diversity of diazotrophs in roots and root environment. The associative diazotrophs isolated from the roots of coconut palm include *Azospirillum amazonense*, *Azospirillum lipoferum*, *Azospirillum brasilense*, *Herbaspirillum frisingense*, *Burkholderia* sp., *Azoarcus* sp., *Arthrobacter* sp., *Xanthobacter* sp. (Prabhu *et al.*, 1998, Thomas and Prabhu, 2003). Acidophilic *Beijerinckia* spp. was the most conspicuous nitrogen fixer in coconut soils, occurring in higher numbers in coconut rhizosphere and rhizoplane indicating a closer association with the palm (Marilyn and Thomas, 1992). A number of efficient strains of phosphate mineralizing bacteria

belonging to the genus *Bacillus*, *Pseudomonas* and *Micrococcus* were isolated from coconut soils (Thomas and Shantaram, 1987). Plant growth promoting rhizobacteria (PGPR) belonging to the genus *Bacillus* spp. form endophytic association with coconut palm as the main component of the bacterial population inside the roots and in leaf tissues (Prabhu *et al.*, 2000). Mass multiplication techniques for these beneficial bacteria were developed and biofertilizer formulations have been prepared using low cost carrier materials.

Inoculation with efficient isolates of diazotrophs significantly enhanced number of main roots, and favoured the production of root branches in coconut seedlings. Preliminary results from field trials with nitrogen fixers and P-solubilisers also gave some indications that these bacteria can be effective to promote the growth and yield of coconut palm. Synergistic effects of various groups of microorganisms have also been brought out, resulting in better plant growth and crop yields. Soil amendments with organic materials favour the development and activity of plant beneficial microbes. It has been established that organic amendments such as coir pith, neem cake, green manures when combined with microbial inoculants resulted in the development of a high population of *Beijerinckia indica* in sandy soils.

Effect of organic resource management on soil biological activity

The coconut growing soils in the coastal belt are characterized by low organic matter content, poor physical properties and low native fertility. The major soil types are laterite, red and coastal sand and they are acidic in reaction (Khan *et al.*, 1978). The soils are light textured which under high rainfall conditions are subject to leaching of nutrients. The major portion of applied nitrogen is lost by leaching. Nutrient management strategies based on organic additions resulted in several beneficial attributes such as improved microbial activity, availability of plant nutrients, organic matter content and physicochemical properties of soil. The organic additions in the form of green manures, composts, crop residues and oil cakes had positive impact on soil fertility and productivity.

In situ cultivation and incorporation of green manure legumes viz., *Pueraria phaseoloides*, *Mimosa invisa* and *Calopogonium mucunoides* resulted in a high level of zymogenic response by different specific and non-specific group of plant beneficial microorganisms (Thomas and Shantaram, 1984).

The green biomass of legumes provided easily decomposable source of energy and carbon source for the microbial groups. Population of function specific microorganisms such as N₂ fixers and phosphate solubilisers also increased considerably. Spore population and arbuscular mycorrhizal colonization were also augmented as a result of green biomass addition. Dehydrogenase, phosphatase and urease activities increased substantially due to the application of green manures. It has been suggested that the soil enzymatic activities could be considered as better indicators of soil fertility. Organic amendment with coir pith, green manures and neem cake when combined with microbial inoculation of *Beijerinckia indica* brought about significant improvement in nitrogen fixation and diazotroph population in coastal sandy loam soil.

Organic manures apart from supplying plant nutrients have profound influence on moisture retention, root growth and nutrient conservation. Organic additions in the form of forest leaves, coconut sheddings, cattle manure and coir pith in conjunction with inorganics, improved soil physical properties, water holding capacity and decreased the bulk density of soil when compared to the application of inorganics alone (Biddappa *et al.*, 1996). The available soil moisture increased to 1.94, 0.87, 1.39 and 1.13% when coir dust, coconut sheddings, forest leaves and cattle manure, respectively were incorporated in littoral sandy soil. Organic manures also enhanced the growth and flowering of coconut seedlings. The establishment of coconut seedlings were better achieved in littoral sandy soils with organic amendments.

Beneficial effects of cropping /farming systems on soil fertility

Cropping/farming systems by raising compatible subsidiary crops and/or integrating with livestock enabled to increase the productivity and net returns from coconut gardens. 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 or crop-livestock components. The beneficial effects were reflected on enhanced soil fertility status, microbial activity and nutrient transformations which were conducive for sustainable crop productivity.

Mixed cropping of cocoa in coconut plantation significantly improved the activity and distribution of various microbial groups (Nair and Subba Rao, 1977). The beneficial flora comprising of bacteria,

fungi and actinomycetes and function specific microorganisms such as, asymbiotic N₂-fixers, P-solubilisers and indole acetic acid producing (IAA) microorganisms were found to be increased in coconut root region under the mixed cropping of cocoa when compared to the monocrop gardens. The increased microbial activity has been attributed to the development of congenial conditions and higher organic matter content due to periodic shedding of leaves and prunings of cocoa. In the multistoreyed cropping system comprising of coconut, black pepper, cocoa and pineapple, the plant beneficial microflora were at an augmented level as a result of synergistic interaction of various crops (Bopaiah and Shetty, 1991a). The activities of soil enzymes, and mineralisation of carbon and nitrogen recorded at an increased level in the system indicated improved biological activities and nutrient transformations contributing to the higher productivity.

The mixed farming system which includes raising of fodder grasses in the interspaces of coconut, integration of animal enterprises including the maintenance of milch cows, and subsequent recycling of cattle shed wastes created highly congenial conditions for higher level of microbial and biological activity in the system (Potty and Jayasanker, 1976, Bopaiah and Shetty, 1991b). The soil fertility benefits recorded from the system include the augmented level of various microbial groups, microbial biomass content, soil enzymes and mineralisation of nutrients. A study on the association of *Azospirillum* in different coconut based cropping systems revealed highest level of root colonization of *Azospirillum* in coconut under mixed farming system in which guinea grass was the major component crop (Ghai and Thomas, 1989). Beneficial symbiotic association formed by arbuscular mycorrhizal fungi have positive influence on the uptake of immobile elements, biological suppression of root pathogens and absorption of water under stress conditions. The mycorrhizal association became more important in marginal soils under low levels of nutrient and water availability. Cropping system had a positive influence on arbuscular mycorrhizal association in coconut. Thomas (1988) reported that intercropping with hybrid napier improved the mycorrhizal status of root (wilt) diseased coconut palms when compared to the monocrop. Cropping system thus enabled better management of natural resources, improved the microbial activities and soil fertility which ultimately resulted in higher biological productivity.

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