

## **Opportunity to Sustain Coconut Ecosystem Services through Recycling of the Palm Leaf Litter as Vermicompost: Indian Scenario (A Technology/ Research Note)**

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### **Abstract**

Coconut (*Cocos nucifera*) is one of the important tropical oilseed crops grown in more than 80 countries. It is called the 'Tree of Life' because every part of the palm finds one or other use in everyday life. India is one of the leading coconut producing countries in the world and many millions of Indians are dependent on this crop for their livelihood.

Many research experiments are in progress to increase the yield of this crop as well as develop post-harvest products that will improve the socio-economic status of the farmers who cultivate it. The coconut cropping system, being unique, offers a wide range of ecosystem services which has not been studied in much detail. A recent paper from Philippines, however, throws some light on the importance of ecosystem services offered by coconut types.

In this article we attempt to enunciate the ecosystem services provided by coconut in Indian scenario and the possibility of sustaining it through the recycling of coconut leaf litter as vermicompost.

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### Status of coconut cultivation in India

India is one of the major coconut producing countries in the world with an area of 1.90 m ha and production of 14744 million nuts. Coconut is a traditional crop grown in the country with a long history of cultivation of more than 3000 years. The crop provides livelihood security for several millions of people who depend on it one way or the other and supplies raw materials to host of industries. The crop is known to offer a multitude of ecosystem services (Garcia et al., 2009) which needs to be studied in depth in India. In this article, the benefits of coconut cultivation to the living beings and as well as the ecosystem services it provides in the Indian scenario is presented. A more properly researched work in this aspect could add to the public opinion and decision makers of its importance and make us realize the need to improve the production and productivity of this crop for sustaining its ecosystem services.

### Ecosystem services

The ecosystem services are the biological foundations that remain essential to economic prosperity and other aspects of human well-being. The services offer a range of conditions and processes through which natural ecosystems, and the species that are part of them, help sustain and fulfill human life. These services maintain biodiversity and the production of ecosystem goods, such as food (including seafood), wild game, forage, timber, biomass fuels, natural fibers, and many pharmaceuticals, industrial products, and their precursors. The harvest and trade of these goods represent important and familiar part of the human economy. In addition to the production of goods, ecosystem services support life (Holdren and Ehrlich, 1974) through the points mentioned below -

- purification of air and water.
- mitigation of droughts and floods.
- generation and preservation of soils and renewal of their fertility and cycling and movement of nutrients.
- detoxification and decomposition of wastes.

- pollination of crops and natural vegetation.
- dispersal of seeds.
- control of the vast majority of potential agricultural pests.
- maintenance of biodiversity.
- protection of coastal shores from erosion by waves.
- protection from the sun's harmful ultraviolet rays.
- partial stabilization of climate and moderation of weather extremes and their impacts.
- provision of aesthetic beauty and intellectual stimulation that lift the human spirit.

The ecosystems services have been divided into four broad categories by the experts. (MEA, 2005, Daily et al., 1997) The following lists represent samples of each:

1. *Provisioning services* include food (including seafood and game), crops, wild foods, and spices, water, pharmaceuticals, biochemicals, and industrial products as well as energy (hydropower, biomass fuels).
2. *Regulating services* consist of carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, crop pollination, as well as pest and disease control.
3. *Supporting services* are related to nutrient supply and cycling, seed dispersal, and primary production.
4. *Cultural services* include cultural, intellectual and spiritual inspiration, recreational experiences (including ecotourism) and scientific discovery.

### Ecosystem services offered by Coconut

Coconut palm is called 'Kalpavriksha', meaning, the tree which gives all that is

necessary for living. Every part of coconut is used for one or the other purposes *viz.* food and beverage, medicine, cosmetics, industrial raw material, construction material, cultural and religious functions etc. It also supports the livelihood of millions of people in India, directly or indirectly. However, these points consider only a part of the benefits that coconut palm offers to the humans, particularly food and monetary. The wider and more relevant fact of coconut cultivation is not only the socio-economic assistance but also the conservation aspects, *i.e.* the ecosystem services it provides. The several benefits coconut cultivation makes available under the four categories of ecosystem services are given in brief –

### **Provisioning services**

The endosperm of coconut and coconut water by itself is an important source of food for many dependent upon this plantation crop. The coconut flower sap obtained on tapping the inflorescence is rich in sugar and is converted into jaggery, sugar, vinegar and sweet or fermented toddy. The coconut oil cake, a by-product in coconut-oil processing, is a valuable cattle feed. The interspaces in coconut farm allow cultivation of many perennial and annual crops that also provide a variety of food and food-products. The palm trunks offer unique support for the trailing of the black pepper vines, an important spices crop that fetches high income to the farmers of Kerala, Karnataka and Maharashtra. Animal farming include free range poultry, duck, goat and cattle rearing too which are source of protein rich food. The excreta of the animals help in rejuvenating the fertility of the soils.

The coconut oil forms an important component of pharmaceutical, biochemical and industrial products highlighting the provisioning services of coconut cultivation. In recent times production of virgin coconut oil (VCO) has become the newest high-value product in market from coconut producing states (Bawalan and Chapman, 2006)

The coconut palm generates lots of biomass which can be used for many useful purposes. It is reported that one hectare coconut farm with

bearing palms generate around 8-11 tonnes of biomass waste (Biddappa et al., 1996) which can serve as source of kitchen fuel for many poor people and can also be recycled to make vermicompost (Prabhu et al., 1998) and produce edible mushroom (Thomas et al., 1998). The plaited coconut leaves is used as roofing and fencing material of many homes.

Coconut shell and husk, coir-pith are a good sources of biofuels. The Coconut Methyl Ester (CME), or the Coconut Biodiesel produced from coconut oil is a renewable source of energy. CME provides excellent lubricity, solvency and detergency. Studies show that the addition of CME results in better combustion, less pollution, and more engine power and could be one of the major source of energy and power production in regions where coconut is grown. For example, it has been reported that coconut biodiesel can yield reductions of 81 to 109% in net CO<sub>2</sub> emissions relative to petroleum diesel (Tan et al., 2004)

### **Regulating services**

Some of the components under regulating services are carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, crop pollination, pest and disease control.

Though very preliminary research efforts have gone into estimating carbon sequestration by cultivation of coconut palm, it is reported based on studies in Vanuatu, South Pacific that coconut plantations fix high quantities of carbon (39 t/ha a year), which is close to that of tropical rainforests (35 t). These plantations are also excellent biomass and litter producers (around 16 t/ha a year of carbon). Moreover, their carbon balance is high, *i.e.* 7 t/ha a year of carbon fixed (after deducting copra harvest yield), which is higher than but comparable to the mean carbon balance of tropical evergreen rainforests (4 t) (Roupsard et al., 2007).

However, more recently, Magat (2009) using the estimated SOC based on the increase in soil organic matter (SOM) presented a preliminary estimate of the total average annual C storage/balance of a bearing coconut

ecosystem equals to 20.1 t C/ha (5.1 t C/ha as coconut biomass C + 15 t C/ha from soil organic C @ 30 cm soil depth). These reports clearly suggest that cultivation of coconut could enhance the sequestration of carbon in soils.

It is also reported that coconut palms help in prevention of soil runoff and soil erosion, particularly the tall varieties giving more protection than the dwarf coconut palms (Avilan et al., 1984). The canopy of the bearing adult palms as well as its undergrowth provides ground cover thereby intercepting raindrops and reducing terminal velocity of raindrops, which detach the soil particles on the top soil. Such protection leads to soil and water conservation which is higher when there are other short season and long-term crops grown in the coconut inter-spaces.

Coconut gardens host different types of insects like the ants, bees, wasps, and earwigs etc that visit or inhabit the coconut palm. Most of these insects are known pollinators (Davis, 1954). In addition to hosting beneficial insects, coconut palm are attacked by coleopterans, lepidopteron and acarine insect pests that cause severe yield loss, damage or death to the palm. Many different kinds of plant pathogenic fungi also are found in the coconut ecosystem causing important economic damage to the palm. These are the fauna that are normally associated with the coconut and they must be playing an overall important role, even if it is damaging or beneficial, in the ecosystem services provided by this plantation crop.

The various coconut based cropping systems has its own effect on the weather parameters and thus could be regulating the climate of that area. Perhaps, because of the dense green canopy put up by the coconut gardens in West Coast of India the microclimate above it must be enhancing the precipitation of the monsoon clouds. Not to mention that such precipitations bring down much needed nutrients like nitrogen, phosphorus and sodium which could be of help to the largely rain-fed grown coconut in Kerala (Vijayalakshmi and Pandalai, 1962). A crop population with a diverse genetic makeup may have a lower risk of being entirely

lost to any particular stress, such as temperature extremes, droughts, floods, pests, and other environmental variables. Crops with different planting times and times to maturity give the farmer the option to plant and harvest crops at multiple points in the season to guard against total crop loss to environmental threats. Cultivation of coconut along the coastal belts has known to save the hinterland from cyclonic storms and tsunamis by absorbing the destructive forces of the wind and water acting and acting as a bio-shield.

### **Supporting services**

The coconut palm is a perennial crop. It starts yielding from 5 or 6<sup>th</sup> year onwards and continues actively up to 40 to 50 years. During the course of its living it constantly mines the soil for nutrients and conversely each year it sheds 8-11 tonnes of biomass wastes some of which are left to decompose in the farm allowing nutrient recycling. The under-story vegetation is also a significant source of nutrient turnover.

Soil microorganisms form one of the major below ground biotic factors involved in recycling of the nutrients effectively in any system. Coconut rhizosphere harbours a wide range of such beneficial microorganisms which take part in improving the nutrient and fertility status of soils (Thomas et al., 1991). The belowground microbial diversity increases from the monocropped coconut garden to multiple cropped coconut gardens and is greatly influenced by the above ground vegetation type (Bopaiah & Shetty, 1991). The functioning of the below ground microbial communities thus greatly influences the stand of the above ground vegetation and both are highly interrelated. This forms an important supporting ecosystem service provided by the coconut based cropping systems.

### **Cultural services**

Cultivation of coconut palm has deep rooted cultural and spiritual connections in India. Growing coconut palm is equated with bringing up a child, to this extent it is involved in the locals' existence. The palm plays an important role in the life of the farmer. Not only it provides materials for living, the de-husked

coconut forms an important offering to the deities in Hindu temples and during the many family and social festivities. Some of the coconut palms, particularly those growing in Lakshadweep islands, produce small sized coconuts that are very popular in temples of remote areas in Northern India. This is because the small sized nuts are easy to transport to these locales and serve the purpose of religious needs. During temple festivals in Kerala where local folk dances are performed many parts of the coconut palm are used for dressing the performers. The coconut inflorescence and the leaves are used as decorative buntings for all social and cultural celebrations in many parts of Southern India. Artists, be it painters, poets, song writers, photographers or film producers never miss to highlight the role of coconut palm in the lives of those dependent upon the crop. Not more can be mentioned about the importance of coconut palm than the State Kerala getting its name from this important plantation crop.

The western Coast of India, from Goa down to Thiruvananthapuram and some parts of eastern Coast lined with the swaying coconut palms making the stretches of the nation into most attractive tourist destinations. The tourism industry benefiting enormously by the palms fringed locales helps generating a substantial amount of income to the local Government and the population that caters to tourism based enterprises. An eloquent commentary on the coconut palm transforming the islands of Golden Barrier Reef in Australia into earthly paradise is reported by Pocock (2005). However, it has become imperative that such tourism must be a responsible one taking care of the environment and respecting the local customs and the community.

To sustain the cultivation of this plantation crop increasing the productivity of coconut to higher levels is one of the main options coupled with smart market policies that can help the farmers. To improve the productivity of coconut the following research areas need to be given more thrust –

1. Improving and sustaining the health and fertility of the soils.

2. Production of elite coconut seedlings with enhanced biotic and abiotic stress tolerance.
3. Irrigation management.
4. Threshold level control of pest and diseases using appropriate managements.
5. Mechanization for harvesting the coconuts and carrying out plant protection measures.

### **Recycling coconut leaves to vermicompost to improve soil health and fertility-**

The vermicompost production technology from coconut palm leaf litter using an indigenous strain of *Eudrilus* sp was standardized at CPCRI, Kasaragod during 1998 (Prabhu et al., 1998). The dissemination of this grass-root level technology is being accomplished by imparting regular trainings and demonstration (Thamban et al., 2010) and supply of nuclear earthworm culture to the end-users by CPCRI (Gopal et al, 2009a). The unflagging interest shown by the farmers, youths and women self-help groups towards this simple technology has allowed it to percolate to all the coconut growing states in India. Continuous financial support from State Agricultural Departments, Coconut Development Board (CDB, India) and National Bank for Agricultural & Rural Development (NABARD, India) has aided in the spread of this technology.

However, the popularity of this technology rests in its simplicity, steady availability of the substrates, less farm/homestead space requirement, low initial investment, and possible management with family/group labour and most importantly providing additional economic returns.

### **Multiple reasons to intensify coconut leaf vermicomposting (CLV) for sustaining ecosystem services offered by coconut–**

We list a dozen and more scientific reasons to intensify the adoption of this technology as a mass movement among the farmers who grow coconut –

**1. Efficient recycling of the recalcitrant coconut leaf litter** - Coconut leaves have around 24% cellulose, 39% lignin and about 8% phenols (Table 1) in them which makes it highly recalcitrant and take 12-18 months to degrade naturally. The indigenous strain of *Eudrilus* earthworm is able to convert this lignin-rich biomass admixed with 10% cow-dung to carbon-rich granular vermicompost within 60-75 days. Thus this technology offers an efficient method of recycling the 6-8 tonnes of leaf litter produced annually from 1 ha coconut garden to 4-5 tonnes of healthy organic manure.

**2. Broad spectrum substrate utilization** - The *Eudrilus* sp can not only consume the coconut leaves, it can also digest pineapple wastes or banana pseudostem or glyricidia leaves or jackfruit leaves or mango leaves or coir-pith when mixed @ 25% w/w with coconut leaves and cow dung (Table 2). Thus the leaf or plant biomass wastes available from intercrops or homestead garden trees grown along with coconut can also be used as substrate for the vermicompost production.

**3. Year round activity** - The coconut palm and many of the trees such as jack fruit and mango commonly grown in homestead are perennial crops that generate large amount of biomass waste continuously. The conversion of these wastes therefore becomes a year round activity for the end-users. The optimum weather conditions for efficient vermicomposting of coconut leaves by *Eudrilus* sp. was 28-32°C temperature and RH of the range 90-95% which coincided with monsoon and post-monsoon periods in coastal tract of Kerala (Fig.1)

**4. Source of organic matter to the soil** - Soil organic matter (SOM) is a keystone component of the ecosystem, which is related to the quantity and variability of plant litter inputs. The coconut leaf vermicompost is bulky stabilized manure with organic C content as high as 17-20% (Table 3). Regular addition of this compost will be able to build of organic matter content of the soil which is the main nutrient source for the plants and microorganisms.

**5. Addition of essential plant nutrients** - CLV contains on an average 1.8% N, 0.2% each of P

and K. From one ton of this manure 18-21 kg of N, 2-3 kg each of P and K approximately (Table 3) can be obtained which can be used as organic manure and help in reducing the inorganic inputs. Though the NPK content is low compared to inorganic fertilizers, other positive aspects (given below) of CLV makes it an ideal low-external input for improving the soil health and fertility.

**6. Provides plant growth promoting hormone** - The CLV contains 10-13% humic acid that improves the establishment of healthy root and shoots system in plants. In addition to humic acid, the CLV also contains indole acetic acid and gibberellic acid which are known plant growth promoting hormones (Table 3).

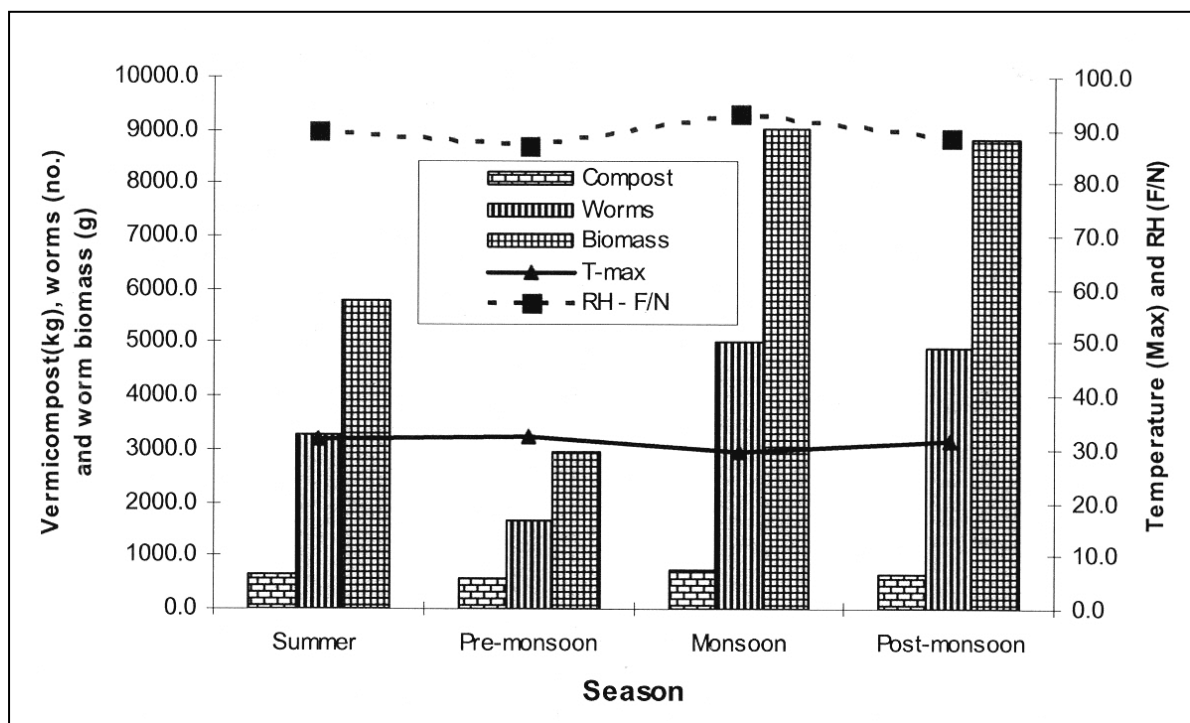
**7. Soil moisture conservation** - The CLV has 116-150% Water Holding Capacity (WHC) (Table 3) compared to 30-40% of sandy loam soils. Addition of the vermicompost to soils particularly to those which have low water retention and low water holding capacity will greatly improve soil moisture conservation particularly in rain-fed cropping areas

**8. Soil pH moderator** - The CLV has pH of 6.2-7.9 (Table3). Its addition to soil, chiefly acidic soils with pH below 5.5, has shown to marginally increase pH which improves the availability of the nutrients to the plants.

**9. Foci of plant beneficial microorganisms** - The CLV has 20% higher microbial biomass compared to sandy loam soil which includes a very large population of plant beneficial microbial communities like nitrogen-fixers, phosphate solubilizers, plant growth promoting *Pseudomonas* and *Bacillus* spp., cellulose degraders (Table 4). The CLV thus become a novel source plant beneficial microorganism which can be tapped for biofertilizer development as well for other biotechnological applications.

**10. Manure for all types of crops** - The CLV is an ideal source of organic manure for all types of crops. It can be one of the main components of the Integrated Nutrient Management (INM). The response to application of CLV can be best noted in case of

**Figure 1. Influence of different seasons on Vermicompost Produced, *Eudrilus* numbers and biomass harvested**



Summer: December to February

Pre-monsoon: March to May

Monsoon: June to August

Post Monsoon: September to November

Source - Gopal et al., 2005

**Table 1. Chemical composition of by-products of coconut palm**

| Recyclable biomass | Cellulose (%) | Lignin (%) | Cellulose: lignin ratio | Nitrogen (%) | Phenol (%) |
|--------------------|---------------|------------|-------------------------|--------------|------------|
| Leaf stalk         | 31.73         | 25.08      | 1.31                    | 0.31         | 2.84       |
| Leaflets           | 23.83         | 38.68      | 0.58                    | 1.00         | 8.45       |
| Bunch waste        | 29.18         | 31.28      | 0.97                    | 0.55         | 2.26       |
| Coir pith          | 22.00         | 34.73      | 0.70                    | 0.46         | 1.40       |
| LSD (P=0.05)       | 5.93          | 8.74       | 0.06                    | 0.41         | 1.28       |

Source - Thomas et al., 1998

**Table 2. Effect of mixing other agro-wastes with coconut leaves on vermicompost production and *Edrilus* multiplication**

| Treatments                         | Initial weight of coconut leaves (kg/tank) | Initial weight of agro-wastes (kg/tank) | Vermicompost recovery (%) | Earthworm multiplication (Numbers) |
|------------------------------------|--|---|---------------------------|------------------------------------|
| Coconut leaves + Banana waste      | 750  | 250                                     | 60.00                     | 10,000                             |
| Coconut leaves +Pine apple wastes  | 750  | 250                                     | 70.00                     | 4,000                              |
| Coconut leaves + Sugarcane bagasse | 750  | 250                                     | 70.00                     | 3,000                              |
| Coconut leaves + Glyricidia        | 750  | 250                                     | 70.00                     | 4,500                              |
| Coconut leaves                     | 1000                                       | -                                       | 72.50                     | 4,500                              |

Source - Thomas, 2005

**Table 3. Chemical, biochemical and nutrition properties of fresh coconut leaf vermicompost**

| Parameter                | Values      | Parameter          | Values        |
|--------------------------|-------------|--------------------|---------------|
| C:N ratio                | 9.95 – 17.0 | Total Nitrogen (%) | 1.8 – 2.1     |
| Total Carbon (%)         | 35-37       | Calcium (ppm)      | 19,500-20,413 |
| Organic carbon (%)       | 17- 20      | Potassium (ppm)    | 1600-4013     |
| Humic acid (%)           | 10-13       | Magnesium (ppm)    | 4290-4679     |
| Indole acetic acid (ppm) | 0.52-1.15   | Phosphorus (ppm)   | 2100-3043     |
| Gibberllic acid (ppm)    | 0.23-1.61   | Sodium (ppm)       | 1411-1525     |
| Total phenols (ppm)      | 10-14       | Sulfur (ppm)       | 2915-3041     |
| WHC %                    | 116-150     | pH                 | 6.2-7.9       |

Source – Gopal, 2008



**Table 4. Population of plant beneficial microbiota in different substrates, gut contents of earthworms reared on these substrates and the vermicomposts produced by the *Eudrilus* sp. (results are an average of 15 replicates and are expressed in cfu g<sup>-1</sup> of fresh sample)**

| Treatments     | Free-living N <sub>2</sub> fixers (x10 <sup>4</sup> ) | <i>Azotobacter</i> (x10 <sup>3</sup> ) | <i>Azospirillum</i> (x10 <sup>4</sup> ) | Autotrophic <i>Nitrosomonas</i> (x10 <sup>3</sup> ) | Autotrophic <i>Nitrobacter</i> (x10 <sup>3</sup> ) | Ammoni-fying bacteria# | Fluorescent pseudomonads (x10 <sup>4</sup> ) | Phosphate solubilizers (x10 <sup>3</sup> ) | Cellulose degraders (x10 <sup>4</sup> ) | Silicate solubilizers (x10 <sup>3</sup> ) | <i>Trichoderma</i> spp. (x10 <sup>3</sup> ) |
|----------------|---|--|---|---|--|------------------------|--|--|---|---|---|
| Substrate A    | 7.0 bc*   | 4.0 c                                  | 2.0 c                                   | 0.02 c  | 0.13 c   | +                      | 6.0 b  | 6.0 c                                      | 4.0 b                                   | 10.0                                      | 1.0 b                                       |
| Gut contents A | 3.0 c   | 8.0 b                                  | 1.0 c                                   | 0.26 c  | 0.5 c  | +++                    | 1.0 c  | 4.0 c                                      | 8.0 a                                   | 6.0                                       | 2.0 b                                       |
| Vermicompost A | 15.0 a  | 0.0 d                                  | 11.0 b                                  | 17.0 b  | 1.9 b  | +++                    | 10.0 a                                       | 20.0 b                                     | 1.0 b                                   | 16.0                                      | 0.0   |
| Substrate B    | 10.0 ab   | 9.0 b                                  | 16.0 a                                  | 1.40 c  | 0.02 c   | ++                     | 1.0 c  | 46.0 a                                     | 11.0 a                                  | 10.0                                      | 1.0 b                                       |
| Gut contents B | 11.0 ab   | 16.0 a                                 | 1.0 c                                   | 0.43 c  | 0.2 c  | +++                    | 1.0 c  | 4.0 c                                      | 1.0 b                                   | 6.0                                       | 4.0 ab                                      |
| Vermicompost B | 4.0 c   | 6.0 b                                  | 8.0 b                                   | 23.0 a  | 2.8 a  | +++                    | 1.0 c  | 4.0 c                                      | 3.0 b                                   | 8.0                                       | 6.0 a                                       |
| CD (p=0.05)    | 5.7   | 3.9                                    | 4.2                                     | 3.51  | 0.55   | ----                   | 2.2  | 8.3  | 3.8                                     | NS  | 3.6   |

# Qualitative estimation of ammonifying bacteria based on ammonification test using Nessler's reagent (+ indicates low, ++ indicates medium and +++ indicates high ammonification, which in turn is indicative of the extent of ammonifiers)

Substrate A = coconut leaf + cow manure (10:1)

Gut contents A = gut contents of earthworms composting substrate A

Vermicompost A = vermicompost excreted by *Eudrilus* sp. reared on substrate A

Substrate B = cow manure

Gut contents B = gut contents of earthworms composting substrate B

Vermicompost B = vermicompost excreted by *Eudrilus* sp. reared on substrate B

\*Means followed by the same letter are not significantly different at P ≥ 0.05 using analysis of variance and mean separation (LSD)

Source – Gopal et al., 2009b

**Table 5. Effect of coconut leaf vermiwash on fresh biomass yield and nodulation of cowpea** (Fresh biomass values are for total 144 plants treatment<sup>-1</sup>, while nodule number is for plant<sup>-1</sup> average in each treatment)

| Treatment       | Fresh biomass (kg) | No. of nodules (% change) | Fresh nodule wt in g (% change) |
|-----------------|--------------------|---------------------------|---------------------------------|
| Control (water) | 25                 | 20                        | 24                              |
| CLV 1:5         | 23 (-8 %)          | 18 (-10 %)                | 23.4 (-2.5 %)                   |
| CLV 1:10        | 28 (+12 %)         | 21 (+5 %)                 | 28.6 (+16 %)                    |
| CLV 1:20        | 34 (+36 %)         | 26 (+30 %)                | 34.3 (+43 %)                    |

**Table 6. Effect of coconut leaf vermiwash on cob yield and fresh biomass of maize** (results are values of 50 plants treatment<sup>-1</sup>)

| Treatment | Cob yield (% change) | Cob wt. in kg (% change) | Fresh biomass in kg (% change) |
|-----------|----------------------|--------------------------|--------------------------------|
| Control   | 42                   | 3.1                      | 9.07                           |
| CLV 1:5   | 44 (+5 %)            | 5.1 (+64 %)              | 11.33 (+30 %)                  |
| CLV 1:10  | 45 (+7 %)            | 4.4 (+42 %)              | 9.87 (+9 %)                    |
| CLV 1:20  | 46 (+10 %)           | 4.8 (+29 %)              | 9.24 (+2 %)                    |

**Table 7. Effect of coconut leaf vermiwash on fruit yield of okra** (results are values of 30 plants treatment<sup>-1</sup>)

| Treatment | Okra fruit yield in kg (% change) |
|-----------|-----------------------------------|
| Control   | 2.82                              |
| CLV 1:5   | 3.76 (+33 %)                      |
| CLV 1:10  | 3.46 (+23 %)                      |
| CLV 1:20  | 3.43 (+22 %)                      |

Tables 5, 6, 7 Source – Gopal et al, 2010

CLV can be best noted in case of vegetable and ornamental crops.

11. **Vermiwash production** - The coconut leaf vermicomposting technology can be exploited to produce a liquid organic fertilizer called vermiwash. The vermiwash produced from coconut leaves contains 2.8 ppm inorganic N, 10.28 ppm phosphorus, 205 ppm potash and 100-142 ppm humic acid (Gopal et al., 2010). Application of vermiwash:water at 1:5 and 1:10 dilutions have shown to improve crop production capacities of soil and enhance the yield of some agronomic and horticultural crops (Tables 5, 6, 7).

12. **Carbon sequestration** - The CLV is a stabilized form of manure which locks up carbon in its organic matter and retains it in the soil more than raw manure or inorganic fertilizer. With its total carbon content ranging from 35-37% and organic carbon around 17-20% consistent application of CLV could gradually raise the level of carbon in the soils. However, research data on the dynamics, stability of the CLV carbon as soil organic C (SOC) over time is needed to be generated for understanding the C-sequestration.

13. **Soilless media** - Coconut leaf vermicompost is granular and light. It can be used as substitute for peat in potting media. Already work done at CPCRI has clearly indicated that coconut leaf vermicompost can be used as an alternative media to potting mixture for raising coconut seedlings in polybags (Reddy et al., 2001). It is therefore very much possible to use this vermicompost as soilless media for raising several horticultural and ornamental plants.

14. **Animal feed** - The earthworm biomass produced during the coconut leaf vermicomposting is a rich source protein. It can be used as feed for poultry, duckery and fish farming (Edwards and Arancon, 2004). The live worms are also good fish bait.

15. **Income generation** - Production of coconut leaf vermicompost adds to the income of the family through the sale of vermicompost as

well as the earthworms. Presently good quality vermicompost is being sold @ Rs. 8-10 /kg and the worms around @ Rs100/kg.

Notwithstanding the many benefits, the vermicompost production technology from coconut leaf litter has its share of shortcomings too viz. i) predation of the earthworms by rodents and ants, ii) ready food for hatched grubs of rhinoceros beetle, iii) requirement of labour for sorting and separation of earthworms and iv) dwindling availability of cow-dung. However, these shortcomings are not insurmountable. Constructing the composting tanks with water channels around the base, covering the tank with nylon mesh or coir-mat or jute-fibre net can easily prevent the entry of ants, insects and rodents. Options for management of rhinoceros beetle in the composting sites include addition of the weed plant *Clerodendron infortunatum* (Chandrika and Nair, 2000) or the entomofungal pathogen *Metarhizium anisopliae* (Gopal et al., 2005). Ushering in mechanization for chopping the coconut leaves as well as using appropriate sieving mechanisms for separating the earthworms and finished compost could overcome the labour issues. Thus several simple technologies are available to overcome some of the limitations associated with the vermicompost production from coconut leaves.

### Conclusion

The many advantages that recycling of coconut leaf litter to vermicompost possesses are good indicators for intensification of this technology at individual farmer level or group level or at community level. Application of the resultant vermicompost can lead to rebuilding health and fertility of the humid tropical soils, slowly perhaps, maintaining the yield of coconut palms and the intercrops, retaining the plant, animal and below ground bio-diversity and thus can help in sustain the ecosystem services offered by this plantation crop to all living beings.

### Large scale production of vermicompost from coconut leaves



6-8 tonnes of coconut leaf biomass is generated from 1 ha garden per year, which can be converted into vermicompost



Coconut leaves + cow dung (10: 1 ratio) is filled in cement tanks and watered for pre-decomposition. Tanks covered with nets to prevent insects/rodents entry



An indigenous earthworm strain *Eudrilus* sp. capable of degrading coconut leaves is added @ 1 worm /kg of substrate after pre-decomposition.



Earthworms feed on coconut leaves, produce cocoons and multiply and convert leaf litter to vermicompost



Coconut leaf litter converted to vermicompost after 60-75 days



Dark granular organic carbon rich vermicompost produced out of coconut leaf litter.

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