International Journal of Innovative Horticulture. 7(2):63-70, 2018 **Review Articles**

Value addition to recalcitrant and voluminous palm biomass residues through vermicomposting technology

Murali Gopal*, Alka Gupta and P. Chowdappa

ICAR-Central Plantation Crops Research Institute, Kasaragod - 671 124, Kerala, India

**Corresponding author: mgcpcri@yahoo.co.in*

ABSTRACT

Among the low external input resources, vermicompost is one the major components of organic farming practices for sustaining soil health, fertility and crop productivity. Vermicompost production is a process that can recycle many of the agricultural refuse into wealth. Many crop residues are now a days being converted to vermicompost. Coconut and arecanut palms are two important plantation crops widely grown in southern India and other states. Put together, about 2.4 million ha is under cultivation for these two palms in India. These plantation crops have the character of generating voluminous quantities of biomass residues that are difficult to decompose naturally because of high lignin contents. Using the earthworms, *Eudrilus* sp., *Edurilus eugeniae* and *Eisenia fetida,* adapted to converting the difficult-to-decompose coconut and arecanut leaves, a unique vermicomposting technology for these palm wastes have been developed at ICAR-CPCRI. As a side-product, vermiwash can also be produced from this technology which can act as liquid organic fertilizer and used in fertigation. In this review, we highlight the production process, field studies and their role in organic farming of the plantation crops.

Keywords: Palm, biomass, composting, earthworms

INTRODUCTION

Coconut (*Cocos nucifera* L.) and arecanut (*Areca catechu* L.) are cultivated in about 2.4 million ha area in India. The crops are grown predominantly in the four southern states *viz.* Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Maharashtra, Orissa, Gujarat, West Bengal, Assam, Chhattisgarh, Bihar, Andaman and Nicobar Islands, and Lakshadweep Islands are other states/UTs where they are cultivated. Annually, more than 25 to 30 MT of highly recalcitrant biomass residues in form of leaves, bunch wastes and husks are generated by coconut and arecanut that keep accumulating because of slow natural decomposition. The use of earthworms to convert and recycle such biomass by vermicomposting technology is an attractive technology for waste to wealth management in agriculture.

What is vermicompost and what are its advantages?

The digested refuse of the earthworms is called vermicast or vermicompost. It usually is partially digested organic matter which undergoes physical, chemical and biochemical changes by the combined effect of earthworm and the microbial activities in the gut of the worm (Edward and Fletcher, 1988). The coconut leaf vermicompost (CLV), produced by *Eudrilus* sp., is dark brown coloured, granular matter possessing highly desirable C:N ratio, high organic carbon and humic acid content and easily available important plant nutrients. It is also rich in plant growth promoting hormones *viz*., indole acetic acid, giberrellic acid and phenolics. Biologically, the CLV harbours high counts of nitrogen fixing, phosphate solubilizing, cellulose degrading and plant growth promoting bacteria like fluorescent pseudomonads and *Bacillus* spp. Application of vermicompost improves the soil aggregation, aeration, and water holding capacity; root growth, microbial activity and the overall crop production capacity of the soil in sustainable manner (Chaoui *et al*., 2003; Gopal *et al*., 2010).

Steps involved in vermicompost production

Selection of species

For vermiculture biotechnology, selection of appropriate earthworm species for vermicomposting is the key step. It involves the following important points:

- The earthworm should be capable of inhabiting and completing life cycle in a medium rich in organic matter.

- It should have high cocoon production rate.
- The incubation period required for hatching of cocoons from the time of laying should be short.
- The newly hatched juveniles should attain reproductive maturity in a shortest period.
- The quantity of organic wastes consumed and subsequently digested and egested per unit time should be high. For this, they should be active feeders throughout the year and the mature worms should have good size and weight. The amount of organic matter consumed per day by the earthworms used for composting is usually more than the half of their own body weight and hence these parameters have relevance.
- The efficiency of assimilation of food and growth rate should be high.
- It should be amenable for domestication, handling and culturing in semi-natural or artificial conditions and media.
- It should have good adaptability to a number of environmental variables.

The important domesticated compost worms are:

- *Eisenia fetida* (European compost worm, Brandling worm, Tiger worm)
- *Eudrilus eugeniae* (African night crawler)
- *Perionyx excavatus* (Oriental compost worm)
- *Lumbricus rubellus* (Redworm)

Eisenia fetida and *Lumbricus rubellus* are more suited for temperate regions. *Eudrilus euginiae* is suited for tropical and sub-tropical countries. For composting city waste, *Eisenia foetida* and *Perionyx excavatus* are preferred. *Perionyx excavatus* is semi-aquatic and may be of use in composting of organic wastes with very high moisture content.

The most ideal species for degradation of arecanut and cocoa wastes is found to be *Eudrilus eugeniae*. *Perionyx excavatus* and *Eisenia fetida* can also be used for decomposition of these organic wastes.

Coconut leaf vermicomposting technology

The coconut leaf vermicomposting involves two aspects: vermiculturing and large scale vermicompost production protocols (Prabhu *et al*., 1998; Gopal *et al*., 2010a).

Vermiculturing protocol

Fallen and weathered coconut leaves are chopped into 15 cm pieces in chaff cutter, and mixed with cow dung slurry in 1:1 ratio. This substrate is pre-decomposed for 15-20 days with constant moisture. The pre-decomposed material is then filled into plastic basins, cement tanks or wooden boxes, or made into 10 cm bed on floor. The nucleus culture of *Eudrilus* sp. is then introduced into the above mixture at the rate of 50 worms per 10 kg of the substrate and properly mulched with dry grass, straw or wet gunny bag. The units are protected from direct sunlight, and watered regularly. Once in a week, fresh cow dung slurry can be added to the material. Within 1-2 months, the earthworms multiply to 300 times, which is used for large scale vermicompost production from coconut leaves.

Large-scale coconut leaf vermicompost production

Coconut leaf vermicompost can be produced in pits, thatched sheds, open ground and cement tanks (Fig. 1). The length and breadth of the production unit can be made as per convenience; however, the depth should be less than 1 metre. Coconut leaves, weathered for 2-3 months, are to be used. After chopping off the thick base, the rest of the leaf can be put as such or in two pieces. They must be stacked with bottom side up in the tank, pit or shed up to 1 feet height. Above this, a layer of cow dung slurry is spread. Three such layers can be accommodated in 1 metre deep cement tank. The ratio of coconut leaves to cow dung slurry must be 10:1 or 10:2 (e.g. 1000 kg leaves: 100-200 kg cow dung slurry). Sufficient moisture must be ensured by sprinkling water regularly, and the whole substrate is allowed to pre-decompose for 2-3 weeks. At the end of this period, 1000 worms per tonnes of substrate are

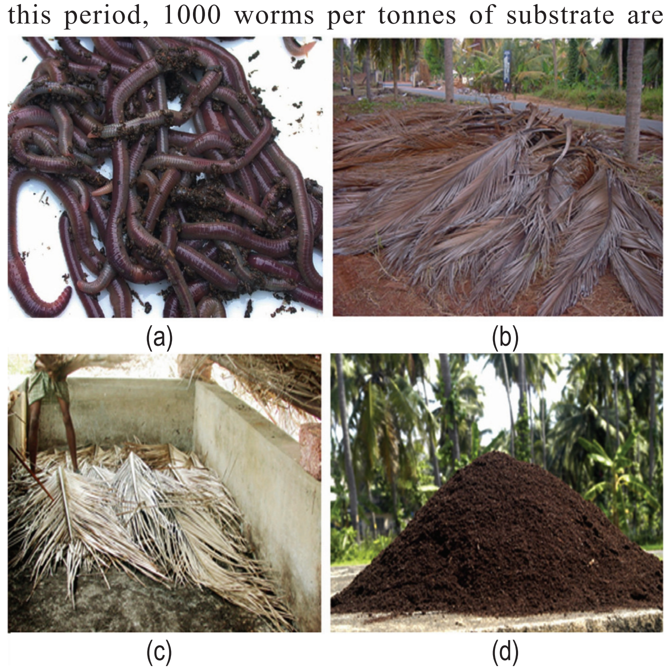

Fig. 1: Coconut leaf vermicomposting technology developed at ICAR-CPCRI. a) Earthworms used for the composting, b) coconut leaves collected from the farm, c) spreading the dry leaves in the compost pits d) vermicompost heap after sieving (Kalpa Organic Gold)

introduced into the tank. Mulching with available organic wastes, dry grass, straw or coconut leaves help to conserve moisture. Watering must be done once a week during monsoon and twice a week in summers. The composting area should be provided with sufficient shade to protect from direct sunlight and rain water. Covering the tanks/heaps/pits with nylon mesh prevents entry of predatory birds, rats and rhinoceros beetle. The rhinoceros beetle can also be managed by application of an entomopathogenic fungus *Metarhizium anisopliae* in the substrate (Gopal *et al*., 2006) as well as crushed leaves of *Clerodendron infortunatum*. Providing water channels around the tanks will prevent entry of ants into the vermicomposting material.

Depending upon the extent of weathering and pre-decomposition, a maximum of 70% of the substrate will be converted to vermicompost within a period of 60-75 days, indicated by the fall in the level of substrate by more than ½ metre in the tank. At this stage, watering should be stopped to facilitate separation of worms from the vermicompost by heaping the compost in the centre. After another two weeks, the vermicompost free of earthworms can be collected from the top layer of the heap, sieved, shade dried and packed. The produce has been branded as 'Kalpa Organic Gold' (Fig.1) for improving the market visibility of the product and the technology. Earthworms accumulated at the bottom of the heap can be sorted and picked by hand and can be used for further composting. The coconut leaves substrate can also be mixed with pineapple waste, banana pseudo stem or *Gliricidia* leaves in 4:1 ratio for effective utilization of other wastes commonly produced in coconut-based cropping system (Thomas *et al*., 2012). The coconut leaf vermicomposting technology not only simply recycles the leaves to manures, but also provides an opportunity to sustain the ecosystem services provided by the crop because of the following points:

Fig. 2: Coconut leaf vermiwash technology developed at ICAR-CPCRI.

Circular carbon economy

Carbon is the energy currency of soil. Its rapid depletion leads to erosion of productive soil, loss of below and above-ground diversity and low agriculture output. The coconut leaf vermicompost is bulky stabilized manure with total carbon content of 35-37% and organic C content as high as 17-20%. Regular addition of this compost will be able to build organic matter content of the soil which is the main nutrient source for the plants and microorganisms. Thus, coconut leaf vermicompost returns carbon to soil and helps in producing higher plant biomass (Gopal *et al*., 2017a).

Replenishes soil with plant nutrients

As this vermicompost contains 1.8% N, 0.2% each of P and K, one tonne of this manure can add 18-21 kg of N, 2-3 kg each of P and K approximately to the soil. It can thus reduce application of chemical fertilizers to a great extent. For example, application of 25-30 kg of vermicompost/ coconut palm can meet all of its N requirement, but only 16% of P and 5% of K which needs to be supplemented *via* other sources. Though the NPK content is low compared to chemical fertilizers, other positive aspects of this vermicompost makes it an ideal low-external input for improving the soil health and fertility.

Source of plant growth hormones

Coconut leaf vermicompost is rich in humic acid that improves the establishment of healthy root and shoot system in plants. It also contains indole acetic acid and gibberellic acid, which are known plant growth promoting hormones.

Conserves soil moisture and adjusts soil pH

With 116-150% water holding capacity, addition of the coconut leaf vermicompost can significantly enhance water holding capacity of low water retention soils. This will greatly improve soil moisture conservation especially in rain-fed cropping areas to help plants overcome water-deficit stress.

Coconut leaf vermicompost has near-to-neutral pH range of 6.2-6.5. Its addition can marginally improve those acidic soils having pH below 5.5 and as a result improve the availability of the nutrients to the plants.

Enhances soil microbial properties

Microbial biomass of this vermicompost is 20% higher compared to normal sandy loam soil. The biomass includes large population of plant beneficial microbial communities like nitrogen-fixers, phosphate solubilizers, plant growth promoting *Pseudomonas* and *Bacillus* spp., cellulose degraders (Gopal *et al*., 2009). The coconut leaf vermicompost, thus, becomes a novel source of plant beneficial microorganisms, which can be tapped for biofertilizer development as well for other biotechnological applications (Gopal *et al*., 2017b).

Multi-crop manure

The coconut leaf vermicompost 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. The response to application of coconut leaf vermicompost can be best noted in case of vegetable and ornamental crops.

Source of liquid fertilizer

Vermiwash a liquid organic fertilizer, can be produced during the coconut leaf vermicomposting process. The vermiwash thus produced contains 2.8 ppm inorganic N, 10.28 ppm phosphorus, 205 ppm potash and 100-142 ppm humic acid. Application of vermiwash : water at 1:5 and 1:10 dilutions have shown to improve crop production capacities of soil and enhance the growth/yield of some agronomic and horticultural crops.

Carbon sequestration

The coconut leaf vermicompost 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 it could gradually raise the level of carbon in the soils and can also lock organic carbon in soil for not less than 20 to 40 years owing to the presence of humic acids in it. The addition of this physically-protected humus organic carbon fraction of the vermicompost significantly improves the soil physical properties that enhance the root proliferation and nutrient acquisition by standing crop. Since the humus organic carbon remains in soil for long periods, even subsequent crops stands benefitted by its application. However, research data on the dynamics, stability of the coconut leaf vermicompost carbon as soil organic C over time needs to be generated for understanding the C-sequestration.

Soilless cultivation

Coconut leaf vermicompost is granular and of lighter density. It can be used as a substitute for peat in potting media. Already work done at ICAR-CPCRI has clearly indicated that coconut leaf vermicompost can be used as an alternative medium to potting mixture for raising coconut, arecanut, cocoa and vegetable seedlings in polybags/pot trays. It is therefore very much possible to use this vermicompost as soilless medium for raising several horticultural and ornamental plants (Gopal *et al*., 2016).

Animal feed

During the vermicompost production, there is multiplication of the earthworm numbers also. The earthworm biomass is a rich source of protein. It can be used as feed supplement for poultry, duckery and fish farming. The live worms are also good fish bait.

Improves farmers' economy

Production of coconut leaf vermicompost adds to the income of the family through the sale of vermicompost as well as the earthworms. If a farmer produces one tonne of vermicompost on his own farm with available infrastructure and substrates, he can earn approximately Rs. 12,000 from the sale of the vermicompost and earthworms, against production cost of Rs. 5500 per production cycle.

Coconut leaf vermiwash technology

Vermiwash is a by-product obtained from vermicompost production technology that can be used as a liquid organic fertilizer for improving crop growth and yield (Ismail, 1997). Vermiwash production can be done basically by two methods. One method involves soaking soil + cow dung + earthworms substrate in excess water in plastic tub and siphoning the wash periodically from the bottom of the tub while another one involves releasing the earthworms in lukewarm water and agitating them gently so as to shock them to secrete higher amount of body fluids and mucus (Kale, 1988) . This liquid organic fertilizer is rich in nutrients and plant growth hormones and its application has been reported to stimulate anthurium, increase soil nutrient status and yield of paddy, biological productivity of marigold, *Aloe vera*, fruit quality of tomatoes, yield of spinach, onion and potato and cowpea.

The Central Plantation Crops Research Institute (CPCRI) developed a simple, farmer-friendly technology for production of vermicompost from the high lignin containing coconut leaves using an indigenous isolate of earthworm

Eudrilus sp. The technology became popular and rapidly spread to many of the coconut producing states *viz.* Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Bihar, Orissa and West Bengal in a span of 10 years. Sale of the nucleus earthworm culture has been a good indicator of the percolation of the coconut leaf vermicomposting technology. Further work done at CPCRI led to standardization of vermiwash production as a value addition to coconut leaf vermicompost production technology (Gopal *et al*., 2010b). Vermiwash production from coconut leaf vermicompost needs the following items -

i) A large plastic drum or earthen pot with a tap fixed at bottom; another small earthen pot to be hung over the drum or bigger pot (Fig. 2),

ii) pre-decomposed substrate *i.e*. coconut leaves + cowdung in 10:1 ratio, w/w basis,

iii) mature coconut leaf vermicompost,

iv) cow dung and

v) coconut leaf degrading earthworm (available at CPCRI, Kasaragod)

The drum or big earthen pot is filled with pebbles, then coarse gravel followed by river sand. This set up acts as a filtration layer. Water is allowed to flow through this such that the filtration layer settles properly. Above the filtration layer items ii), iii) and iv) are filled in 4:4:1 ratio, w/w basis. Water is added to maintain the moisture content at 40% (e.g. 4 l water for 10 kg substrate) followed by addition of the earthworms (5 adult worms for 1 kg of substrate). The whole unit is kept undisturbed for 10 days allowing the earthworms to feed on the substrates. After 10^{th} day, water is added as a trickle from the small pot hung above the drum or bigger pot. After a period of 30 days, the vermiwash that is collected at the bottom of the barrel is drawn out from the tap and stored for use. Subsequent collections were made at weekly intervals for a month. The vermiwash thus obtained is clear brown colour liquid (Fig. 2) which is odour free possessing alkaline pH, containing major and minor nutrients, growth hormones, humic acid and plant beneficial bacteria particularly the fluorescent pseudomonads.

To determine the concentration at which the vermiwash should be applied, an *in vitro* seedling vigour index bioassay at different concentration levels was carried out on cowpea and paddy seeds. Based on the *in vitro* results, the efficacy of the coconut leaf vermiwash on growth and yield of cowpea, okra and maize was carried out in field studies at CPCRI. Further, to validate the results obtained in the in-house studies, field trials were conducted in collaboration with the Krishi Vigyan Kendra-KVK (Farm Science Centre), Kasaragod at farmers' plots at Majal and Edneer area in Kasaragod District (Gopal *et al*., 2010c). Two leading farmers, one from Majal and another from Edneer panchayath of Kasaragod District were selected for the field trials. The farmers were supplied with sufficient quantities of coconut leaf vermiwash produced at CPCRI for the validation. They were asked to apply the test plots only with vermiwash diluted with water at 1:5 ratio once in a week followed by regular irrigation with water. The farmers raised the respective crops from seeds obtained from KVK, Kasaragod, Agriculture Department, Kasaragod or the seeds maintained by themselves from their previous harvests. They applied poultry manure + neem cake as basal organic inputs during the preparation of the field followed by inorganic fertilizer mix 17 during the middle stage of crop growth. This was considered as farmers' treatment and it was compared with coconut leaf vermiwash treatment. Irrigation to the crops was done by ground water twice or thrice in a week depending on equirement. The farmers allocated 5 rows of amaranthus, cow pea and chillies and 6 pits for bitter gourd for evaluating the effect of coconut leaf vermiwash while the rest of the plots received the inorganic fertilizer treatment. The farmers were asked to record the yield from both the treatments and any other observations they noticed. The rhizosphere soils from the vermiwash treated plots and the farmers' treatment plots were analyzed for soil microbial population and enzyme activities.

Application of appropriately diluted (1:5 to 1:20) coconut leaf vermiwash increased germination and seedling vigour index of cow pea and paddy seeds in laboratory bioassays. Cowpea showed a maximum vigour index of 11.55 at 1:10 dilution, whereas, paddy gave 11.9 at 1:20 dilution. This indicated that appropriately diluted vermiwash had a positive effect on the percent seed germination and growth of the cow pea and paddy seedlings. In response to vermiwash application, both crop seedlings produced a profuse growth of fine root hairs, which was lacking in the seedlings that received plain water.

Field trials conducted on cowpea, maize and bhendi in Institute farm showed its capacity to enhance the biomass and yield of the crops accompanied by increase in soil microbial populations, enzyme activities and organic carbon content of the soil. For the field experiments, three dilutions of the vermiwash *viz*. 1:5, 1:10, 1:20 were tried based on the outcome of the laboratory seedling bioassays. It was observed that application of vermiwash enhanced the growth of cowpea at 1:10 and 1:20 dilutions with the latter dilution giving highest percentage of increase in fresh biomass (36%), higher nodule numbers (30%) and nodule fresh weight (43%) when compared to control and other vermiwash treatments (Table 1).

Table 1: Effect of coconut leaf vermiwash on fresh biomass yield and nodulation of cowpea

Treatment	Fresh biomass (kg)	No. of nodules (% change)	Fresh nodule wt. in g (% change)
Control (water)	25	20	24
Vermiwash1:5	23 (- 8 %)	18 (- 10 %)	23.4 (- 2.5 %)
Vermiwash 1:10	28 (+12 %)	21 (+5 %)	28.6 (+16 %)
Vermiwash 1:20	34 (+36 %)	26 (+30 %)	34.3 (+ 43 %)

In case of maize, the total number of cobs produced increased with increasing dilution of the vermiwash; however, the weight of cobs and fresh biomass weight of the plants were recorded highest (64% and 30% above control) at 1: 5 dilution of the vermiwash (Table 2).

Table 2: Effect of coconut leaf vermiwash on cob yield and fresh biomass of maize

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

Similarly, an increase in bhendi yield by 33% over control treatment was also recorded when vermiwash was applied at 1:5 dilution (Table 3). The field studies, thus, amply supported the fact that application of vermiwash increased the biomass and yield of a range of crops.

Table 3: Effect of coconut leaf vermiwash on fruit yield of bhendi

Treatment	Bhendi yield in kg (% change)
Control	2.82
Vermiwash 1:5	3.76 (+33%)
Vermiwash 1:10	3.46 (+23%)
Vermiwash 1:20	3.43 (+22%)

Vermiwash application yielded 75 and 200 kg cow pea and bitter gourd, respectively, at farm in Majal and 55, 155 and 10 kg of amaranthus, cowpea and chillies, respectively, at Edneer farm (Table 4). It is clearly seen that the application of vermiwash produced yields on par or slightly less compared to plots receiving farmers' regular inputs of organic and inorganic fertilizers. Agronomic performance of organic systems elsewhere have reported reduction in crop yields by up to 20% with concomitant reduction in fertilizer and energy inputs by 34–53% and pesticide input by 97%. However, the farmers opined unanimously that application of coconut leaf vermiwash helped in production of better quality vegetables. They reported that application of vermiwash produced amaranthus possessing dense root hairs, broad and tender leaves with deep colour and minimum pest and disease incidence (Table 4). The crop stand of bitter gourd, cowpea and chilli was also very lush.

Table 4: Yield response of vegetable crops to application of coconut leaf vermiwash and other observations recorded by the farmers. (The results are total yield from 5 rows/pits)

Place	Crop	Yield(Kg)	Farmer's remarks on effect of vermiwash on growth and yield quality of vegetables
Majal	Cowpea	75(81)*	Good quality of produce, better plant growth, good storage quality of the produce, softer beans
Majal	Bitter gourd	200 (218)*	Very good quality of produce, healthier look of the plants, early bearing, delayed ripening of fruits
Edneer	Amaranthus	55(59)*	Bigger leaf size, deep leaf colour, no pest and disease attack, more hairy roots, harvested plants showed wilting after longer duration
Edneer	Cowpea	155 (156)*	Better plant growth, produce was of good quality and more tastier
Edneer	Chilli	10(12)*	Rich green colour of the leaves, better plant growth, good pungency

* Yield from plots receiving farmers' inputs of poultry manure+neem cake as basal application followed by inorganic fertilizer mix

Studies on soil microflora and enzyme activity measurements were used as indicators of soil functionality and thus, indicators of soil. It was observed that application of coconut leaf vermiwash stimulated the population of all the soil microbial communities, particularly the plant beneficial group of free-living nitrogen fixers, phosphate solubilizers and fluorescent pseudomonads, which form an important fraction of the plant growth promoting rhizobacteria. Similarly, the activities of three important soil enzymes *viz*., dehydrogenase, phosphatase and urease increased sharply in the vermiwash applied plots compared to the poultry manure + neem cake and inorganic fertilizer applied plots .

Coconut leaf vermiwash has also been reported to have a deleterious effect on the juveniles of burrowing nematode, *Radopholus similis*, root-knot nematode, *Meloidogyne incognita*, root lesion nematode, *Pratylenchus coffeae* and spiral nematode, *Helicotylenchus multicinctus* which are some of the major nematode pests of crops in coconut based high-density multi-species cropping system. Vermicompost and liquid vermiwash produced from other crop residues have also been found to be effective as an organic source of fertilizer comparable with inorganic source of fertilizer and biological disease prevention in a number of vegetable crops (Banu and Iyer, 2006).

Thus, we observed in vermiwash treated plots a clear correlation between increases in microbial population with increased enzyme activities as much of the soil enzymes originate from microbial biomass. This clearly indicated that vermiwash had a positive influence in building up the soil quality and health when compared to farmers' inputs, which must have resulted in production of quality vegetables. Improvement in soil fertility and biodiversity in organic farming has been well documented by many workers.

Vermiwash can improve soil quality and health and production of quality vegetables. However, proper dilution of vermiwash is important for getting desirable results. For vegetative growth, vermiwash at 1:10 dilution and for economic yield output like fruits and cobs, 1:5 dilution was observed to be appropriate. It must also be noted that the positive effect of application of vermiwash alone as fertilizer by itself cannot be sustainable as it has low concentrations of major and minor nutrients. It needs to be combined with other organic manures to make it more effective, particularly when used for plantation crops. The experience thus points to the fact that coconut leaf vermiwash can be used as one of the eco-friendly components of organic farming for sustainable soil health and fertility.

Arecanut leaf vermicomposting

On an average, 8 to 16 tonnes of leaf wastes are available from one ha of areca garden per year. Direct application of these wastes in the garden will take long time for decomposition and will not meet the nutrient demand of the crop immediately. Hence, these materials can be composted using earthworms effectively and used as organic manure in areca gardens (Chowdappa *et al*., 1999).

To prepare vermicompost, areca wastes are chopped into small pieces of 10 cm and heaped. The heap is sprinkled with water daily and kept for two weeks. Then the chopped material is arranged in beds of one metre width and convenient length. Cement tanks or trenches can be used for this purpose. A layer of 10-15 cm waste material is alternated with 2 cm layer of cowdung over which earthworms, two species of earthworms, *Eudrilus eugeniae* and *Eisenia fetida*, are released at the rate of 1000 numbers per square metre. The wastes converted into fine granular, odourless vermicompost within 60 days. About 80% recovery of vermicompost from these wastes is possible. During this period, the earthworm population also doubled.

Vermicomposting improves the total N content to 1.38% from initial level of 0.71% in arecanut leaf wastes (Chowdappa *et al*., 1999). The increase in N concentration of vermicompost can be attributed to high protein content of earthworm tissue and enhanced microbial activity causing transformation of the soluble N in to microbial protein, thereby preventing N loss. This can also be attributed to conversion of nutrients in organic waste to more soluble and available forms. The composition of other nutrients is more or less same in organic wastes and compost. Overall, arecanut leaf vermicompost is rich in N, P, Ca, Mg and micronutrients (Table 5). About 4 kg of vermicompost per palm per year meets the N and P nutrient demand of arecanut while potassium needs to be added through other sources like MOP, arecanut husk or *Gliricidia*. In other words, the arecanut wastes recycled in the form of vermicompost have potential to meet 50% N, 32.5% P and 26% K requirement of arecanut.

Table 5: Nutrient composition of dry arecanut leaves and its vermicompost

Nutrients	Arecanut	
	Dry leaves	Arecanut leaf Vermicompost
Organic carbon (%)	44.2	33.1
N (%)	0.71	1.38
P(%)	0.08	0.35
K(%)	0.94	0.98
C:N ratio	62.2	23.2
Cu(ppm)	100	120
Fe(ppm)	1746	2561
Zn(ppm)	307	396
Mn(ppm)	82	242
pH		7.3

Arecanut leaf vermiwash production

Arecanut leaf vermiwash can be produced using 250 l barrel. For this, an empty barrel with one side open is taken. On the other side, a hole is made to accommodate the vertical limb of a 'T' jointed tube in a way that about half to one inch of the tube projects into the barrel. To one end of the horizontal limb is attached a tap. The other end is kept closed. This serves as an emergency opening to clean the 'T' jointed tube if it gets clogged. The entire unit is set up on a short pedestal made of few bricks to facilitate easy collection of vermiwash.

Keeping the tap open, a 25 cm layer of broken bricks or pebbles is placed. A 25 cm layer of coarse sand then follows the layer of bricks. Water is then made to flow through these layers to enable the setting up of the basic filter unit. On top of this layer is placed a 30 to 45 cm layer of loamy soil. It is moistened and into this about 50 numbers each of the surface (epigeic) and sub-surface (anecic) earthworms are introduced. Cattle dung pats and hay is placed on top of the soil layer and gently moistened. The tap is kept open for the next 15 days. Water is added every day to keep the unit moist.

On the 16th day, the tap is closed and on top of the unit a metal container or mud pot perforated at the base as a sprinkler is suspended. 5 litres of water (the volume of water taken in this container is one fiftieth of the size of the main container) is poured into this container and allowed to gradually sprinkle on the barrel overnight. This water percolates through the compost, the burrows of the earthworms and gets collected at the base. The tap of the unit is opened the next day morning and the vermiwash is collected. The tap is then closed and the suspended pot is refilled with 5 litres of water that evening to be collected again the following morning. Dung pats and hay may be replaced periodically based on need. The entire set up may be emptied and reset between 10 and 12 months of use.

Vermiwash is diluted with water (10%) before spraying. This has been found to be very effective on several plants. If need be vermiwash may be mixed with cow's urine and diluted (1 litre of vermiwash, 1 litre of cow's urine and 8 litres of water) and sprayed on plants to function as an effecting foliar spray and pesticide. Vermiwash obtained by mixing vermicompost and water at 1:10 ratio contains 250 mg/kg NO_3-N, 132 mg /kg P and 88–133 mg/kg K and has also been successfully used in fertigation of arecanut (Sujatha and Bhat, 2013).

Vermicomposting of arecanut leaves can be taken up as a commercial venture by farmers to improve profits and also to meet the nutrient demand of either main or intercrops.

CONCLUSIONS AND FUTURE RESEARCH

Recycling of coconut and arecanut leaves to compost through vermicomposting technology is a viable and effective option to convert large quantities of biomass residues from coconut and arecanut garden to useful manure. The vermicomposting technology can also be exploited for producing vermiwash, which is liquid organic manure. Application of vermicomposts has clearly shown to improve soil health and fertility in an ecologically safe manner. However, the low concentration of potassium element in the vermicomposts needs to be addressed in a scientific manner to improve the overall nutritive value of the manure.

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