Objective 6
Assessment on the use of Coconut wood harvesting and processing residues for by-products

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Coconut Veneer project

Development of advanced veneer and other product from coconut wood to enhance livelihoods in South Pacific communities

Australian Government
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1.0 Introduction

In South Pacific Island countries many coconut palms are of an older age and now provide only low nut yields. Identified as senile, these palms are ready for removal to be either replaced, or the land converted to alternative use.

One established Fijian company, Pacific Green, produces exotic tropical style furniture from coconut palm logs extracted from senile palms. To expand the range of products and potentially add value to the coconut wood product supply chain, a rotary peeled veneer industry is now being investigated as an option for the use of logs extracted when the senile palms are harvested in future. If this option proves attractive, strategic operations will need to be considered to address an increasing demand for both saw- and peeler-logs.

The distribution of vascular fibre bundles longitudinally arranged throughout parenchyma ground cortex of a coconut palm stem is a key determinant of the palm's wood properties. The outer periphery of the stem and the lower stem has a higher basic density more suited to solid wood products (Bailleres, H., et al. 2010). This means after palm harvesting operations for suitable solid coconut wood products, a large volume of lower density palm material remains.

To assist in identification of various uses for harvest residue material and the residues from processing the coconut palm logs for solid wood products, the Centre for Sustainable Architecture with Wood (CSAW) at the University of Tasmania has undertaken a number of trial studies which aimed to investigate the suitability of using coconut log processing residues, coconut palm woodchips and other harvest residues materials for the following options:

- A residential and industrial fuel source.
- A growing medium for mushrooms.
- A growing medium for plants.
- A feedstock for biochar pyrolysis.
- A feedstock material for compost production.

This report presents findings and conclusions drawn from the trial studies, and the literature reviewed.

About this report

This report is part of the ACIAR-funded coconut veneer project *FST/2009/062: Development of advanced veneer and other product from coconut wood to enhance livelihoods in South Pacific communities.*

The project team includes researchers and collaborators from the University of Tasmania's Centre for Sustainable Architecture with Wood (CSAW), the Queensland Department of Agriculture and Fisheries (QDAF) Innovative Forest Products Team, the Pacific Community (SPC), the Fiji Department of Fisheries and Forestry, the Samoan Ministry of Natural Resources and Environment, the Solomon Islands' Ministry of Forestry and Research, and industry in Australia and Pacific Islands. The project supports economic development in Fiji, Samoa and the Solomon Islands and includes activity in market and value-chain assessment, log harvesting, veneer production and product manufacture, and the development of viable uses for coconut residues at the harvest site or the production facility.

More information about the project is available at www.cocowood.net.

2.0 Palm harvest residue- potential volumes

This section examines the potential volume of coconut palm harvest residues that would be available at both a regional estate and community plantation level, if present and future levels of palm senility are to be addressed through planned harvesting.

2.1 Regional estate level harvest residues

Many coconut palms in plantations across the South Pacific Islands are old and yield a low nut productivity. For example, a typical 25-year-old coconut palm may produce 35 nuts a year while a 60-year-old palm only 4 nuts. Palms of such a low nut productivity are known as senile.

According to the most recent estimates in a report by the Food and Agriculture Organization of the United Nations (2014) the coconut area in Fiji, through either cyclone events or by not replacing palms previously extracted, has gradually declined to approximately 64,000 hectares (ha), of which approximately 60% or 39,000 ha are already senile and due for replacement. See Table 1. The same report estimates that through replanting and estate development after devastating cyclones in 1990 and 1991, the coconut plantation area in Samoa has gradually increased to 93,000 ha and as these are relatively recent plantings only approximately 16% of the total estate is considered senile. An International Trade Centre study (2010) estimates the area of coconut plantation in the Solomon Islands is 59,000 ha. The age structure of the Solomon Island palms is relatively young with about 50% of the existing stands under smallholder cultivation. These were planted in the 1970's, though a sizeable area of coconuts was planted after 1945. It is estimated that approximately 20% of the total Solomon Island's estate is now senile. Assuming a survival rate of 95%, as observed in coconut palm log selections in Savusavu, Fiji. 2015, an estimate of the number of palms considered productive (age 60 years and under) and the total estate palm numbers are also shown in Table 1.

In addition to addressing the existing palm senility, which will likely occur over an extended period, if the total estate area is to be maintained for future production there needs to be a scheduled replacement of the productive palms in the plantation, as they also become senile and much less productive. This means that to maintain a 60 year plantation rotation, for example, 1/12th of the total estate is replaced every 5 years. This results in additional logs available for coconut wood products, and extra residue material to that produced by removal of the senile palms alone.

Table 1: Estimate of the productivity structure of South Pacific Island coconut palms estates.

	Fiji	Solomons	Samoa
Total area of coconut plantations (ha)	65,000	59,000	93,000
Percentage area of senile palms	60	20	16
Total area of senile palms (ha)	39,000	11,800	14,880
Estimated number of existing senile palms	3,705,000	1,121,000	1,413,600
Present total number of productive palms	2,470,000	4,484,123	7,421,400
Total number of palms in the estate @95% survival	6,175,000	5,605,123	8,835,000

2.2 Community level smallholding harvest residues

The final decision to harvest and replace coconut palms will likely be made at the community level where tenure over smallholding areas exists. To examine the potential volume of harvest residue material that would be available from a typical smallholding, a 20 ha plantation area (block) has been considered as a representative model. Table 2 shows the typical stem numbers from a 20 ha block and an estimate of the volume of residue material that would be potentially available every 5 years, from a block of this area.

The estimates were made using the following assumptions:

- Existing levels of palm senility are addressed over 50 years for plantations in Fiji and 30 year periods for plantations in the Solomon Islands and Samoa.
- The plantation rotation period is 60 years, therefore an average of 1/12th of the palms in the 20 ha block will become senile every 5 years.
- A plantation will be harvested for senile palms every 5 years.
- Average height of a 60 year old palm is 35 m.
- Average diameter of the palm is 30 cm (over height).
- A six metre butt (bottom) log from 80% of the senile stems removed will be extracted for solid coconut wood products.

Table 2: Estimated number of senile coconut palms and an estimate of the volume of harvest residue that would be available from a typical 20 ha plantation in a 60 year rotation period that was harvested every 5 years. Note that the residue volume estimates do not include the palm top frond material.

Years	Fiji 20 ha No. of palms	Fiji 20 ha Vol.m^3 of residue	Solomon Is. 20 ha No. of palms	Solomon Is. 20 ha Vol.m^3 of residue	Samoa 20 ha No. of palms	Samoa 20 ha Vol.m^3 of residue
Post immediate harvest	190	390	142	291	115	235
Post harvest year 5	171	351	180	369	115	235
Post harvest year 10	171	351	180	369	172	352
Post harvest year 15	171	351	180	369	172	352
Post harvest year 20	171	351	180	369	172	352
Post harvest year 25	171	351	180	369	172	352
Post harvest year 30	171	351	133	272	134	274
Post harvest year 35	171	351	133	272	134	274
Post harvest year 40	171	351	133	272	134	274
Post harvest year 45	171	351	114	233	134	274
Post harvest year 50	57	117	114	233	134	274
Post harvest year 55	57	117	114	233	134	274
Post harvest year 60	57	117	114	233	134	274

The estimates in Table 2 show the volume of the harvest residue that will exist until the present levels of senility are addressed (10^{th} harvest- 45 years after the initial harvest). Individual stems can be regarded as being in three usable segments:

1- A lower log extracted for solid wood product processing.
2- An upper residual palm stem.
3- The palm fronds, which can be processed for by-products.

The removal of a six-metre butt-log from 80% of senile palms, the percentage of logs recovered satisfying the specification for peeler logs in Savusavu, Fiji in 2015, means that on average only approximately one-sixth of the palm's stem is extracted for solid wood product processing.

Earlier researchers investigating the use of this resource for sawn products (Bailleres H, et al. 2010) found that the tissue of the coconut palm above a six-meter butt-log was of lower density and unsuitable for sawn product processing. During this project, the same research group established improved veneer peeling techniques for palm logs using the same six meter limit. Given this, the option to peel logs extracted from higher in the stem now warrants further study. It should also be noted that the above residue volumes are for wood material from the palm stem and that each palm felled will have a frond top, which will require special consideration: The fronds and palm stem tops meristem region are a green material high in nitrates and sugars, and will therefore potentially contain more active populations of pests and disease, or would quickly attract them if left on the ground after harvesting.

The following sections of this document investigate a number of processing options for the coconut palm of harvest residues.

Figure 1: Typical coconut plantation showing the large volume residue material that exists after harvesting the palms.

3.0 Palm harvest residues as fuel resource

This section examines the potential use of coconut palm harvest and coconut log processing residues as a potential fuel source for residential and both small, and large-scale industrial use. The energy content of coconut palm wood is not high by comparison to expensive imported liquid fuels. See Table 3. However, it can be readily compared to other biomass wood wastes as an alternative fuel-wood. If available as waste residue after harvesting senile coconut palms, this additional fuel source may be particularly attractive for residential and industrial use in remote rural locations where the landscape is not heavily timbered.

3.1 Coconut palm as fuel-wood for residential use

Forestry and wood residues are an important fuel source in Fiji, especially for the 54 percent of its population in rural areas. Recorded fuel-wood consumption in the domestic and small-scale commercial sector has shown a fluctuating but increasing trend and it is suspected that fuel-wood consumption in rural areas has been underestimated (Leslie, A. and Tuinivanua, O. 2010). Estimates of fuel-wood use by residential households (Mario, R. 2000) show the average biomass consumption rate is:

- 378 kg per household per year for urban residents
- 1030 kg per household per year for rural residents

3.2 Coconut palm as fuel-wood for industrial use

South Pacific Island countries import all their petroleum and liquid gas in the form of finished products, with the market shared by three international oil companies, British Petroleum (BP), Shell and Mobil. Liquid Petroleum Gas (LPG) is also imported and distributed by companies, Fiji Gas and Blue Gas in Fiji. Due to the high cost of importation, a major proportion of the Islands energy requirement is from indigenous energy resources such as hydro, wood and bagasse (Mario, R. 2000). The following table shows a comparison of the gross energy content of various fuel resources presently used in the South Pacific Islands:

Table 3: A comparison of the energy content of various fuel types used across the South Pacific Islands (derived from Mario, R. 2000)

Fuel	Gigajoules per Tonne
Automotive Gasoline or Diesel	46
Liquid Petroleum Gas	49.4
Coconut Oil	38.4
Charcoal	30.0
Wood waste @ 40 % moisture content	10.8
Wood waste @ 12 % moisture content	17.1
Coconut palm wood	11.5
Coconut shell and husk	14.0
Sugar bagasse	9.7

Note: These values are indicative and will depend on fuel source, time, temperature and other values.

3.2.1 Copra Drying

When the sun's radiation is not utilised as an energy source for drying, the copra industry generally burns nut residue (coconut shell and husks) to heat and dry the copra. Based on tonnes of copra produced by the heated air drying method, the following mass of residues are used (Mario, R. 2000):

- 2.5 tonnes coconut residue consumed / 1 tonne copra produced using traditional "smoke dryers".
- 1.25 tonnes coconut residue consumed / 1 tonne copra produced using "hot-air dryers".

The dryers employed to dry copra usually have simple air-vent and fire-pit arrangement to provide a heat source. The figures shown in Table 3 indicate coconut palm harvest residues could replace the traditionally used coconut shell and husk fuel as an alternative fuel source.

3.2.2 Electricity Supply

The use of wood residues for electricity generation is limited to one wood-based industry at Labasa, Fiji - Tropik Woods Industries Limited (TWIL). Initially TWIL had an existing 3 Megawatt (MW) generator for its own use and later added a further 9.3 MW plant, upon agreeing on a power purchase agreement with Fiji Electricity Authority to supply approximately 75 gigawatt-hours per annum into Fiji's national grid. Over 140,000 tonnes of wood waste are required to generate that power, which means TWIL not only utilises all of its available fuel and logging residues, but also requires substantial supplementary fuel. (Leslie, A. and Tuinivanua, O. 2010). Coconut palm harvesting to address senility could provide a waste biomass resource that would offer a fuel energy content similar to the wood waste presently used. See Table 3. If electricity demand were sufficient and the economics favourable, then this plant could be expanded to provide more power. Alternatively, new plants and supporting infrastructure could be installed at locations with enough demand and available local residues as a fuel source.

Bagasse, the fibrous residue of sugar cane which remains after the crushing operation is used as a fuel source for the boilers in the production of sugar. The boiler units range in size depending on the size of the sugar-cane production in a region. Often the larger units are capitally expensive and in many countries the surplus energy generated during the cane-crushing period is generated back to the electricity grid (Naude, D. 2001). Sugar production is seasonal and in order to return investment on the capital plant, an alternative fuel source should be available to maximise electricity generation during the non-crush period. If a regular and efficient fuel source such as coconut wood palm harvesting residues were available and the economics favourable, then plant equipment could be upgraded or newly installed to deliver additional heat energy for electricity production.

3.2.3 Timber drying

In solid wood processing, to deliver enough heat energy to continuously run a larger kiln or a large jet-box veneer sheet dryer, an operation would need a heat plant with a capacity of 12-20 Megawatts per hour. The larger industrial water-tube boilers are usually regarded as the most cost efficient types to run and maintain, and after investigation of alternatives and discussion with heat engineers, proved to be the optimal choice as generally more people are certified and available to operate this type of boiler.

For larger-scale drying operations, shredded wood residue as a biofuel is usually considered the only cost effective fuel source option. As an example, approximately 30,000 tonnes per year of shredded wood residual product is required for the boiler servicing a jet-box veneer dryer capable of processing approximately 75,000 cubic metres of veneer per year, operating on a 24 hours per day, five and a half days a week basis. This volume of material can be sourced from on-site veneer production local sawmilling or forest harvesting. See Figure 2. These figures are based on a requirement of approximately 500 kg of green biomass fuel (at about 50% moisture content) per MW per hour (N. Holmes 2014 pers. comm., 2 May).

If either a coconut timber or veneer product industry develops to utilise harvested senile palms, then additional energy will be required for drying the material. Potentially, this could be generated from the partial use of the harvest residues as a fuel source for the heat-plant. A major advantage is that the residue material is likely to be in close proximity to the milling or peeling operation, which would substantially reduce transportation costs, the main factor which generally determines the viability of biomass as a fuel source option.

Figure 2: Typical mill residues as a fuel source from rotary veneer peeling

4.0 Palm harvest residue for growing mushrooms

This section reports on findings and the results of trials performed to investigate the potential use of coconut palm woodchip as a growing medium for mushroom production. Anecdotal evidence suggests that there is potentially a high-value market from hoteliers across the South Pacific Islands willing to pay premium prices for fresh produce to satisfy needs of their mainly affluent clientele.

Previous research (Gibe, ZC. 1985) examining the potential available carbohydrates in coconut wood found the following percentage levels existed in their samples tested:

- Lignin 25.1%
- Holocellulose 66.7%
- Pentosans 22.9%

These results appear favourable for mushroom production, which as a member of the fungi family must obtain carbohydrates and other nutrients by growing on an organic medium.

There are two main types of substrate for mushroom production: whole logs, and a sawdust-woodchip mixture. Typically, little preparation and knowledge is required to use logs for mushroom production, although growing and harvesting from logs takes much longer, and product yield is lower, when compared to growing mushrooms in bags of sawdust or woodchips. Bag cultivation using a sawdust/woodchip substrate is the usual commercial production method, although it means higher preparation costs, higher skill levels and capital investment in controlled growing environments are necessary. Given the potential for a small-scale industry on the South Pacific Islands, we trialled the sawdust/chip bag-growing method. A literature search resulted in no previous published research on the use of coconut wood as a growing medium for mushrooms, therefore initial testing as a growing medium should indicate the materials suitability.

The aim of the study reported in this section is to examine if chipped and sieved coconut wood, as shown in Figure 3, can be utilised as a suitable growing substrate for mushroom production in a Pacific Islands' region climate. The outcome informs interested project partners of the potential to further develop this growing method.

Figure 3: Coconut of various chip size

4.1 Method

Twenty-four bagged samples were trialled. All equipment and inoculated grain required for the trial was purchased from New Generation Mushroom Supplies in Melbourne, Australia.

The following cultivation procedure was followed:

1. The following formulation derived from Stamets, P. (2000) was used as a mushroom growing medium:
   - 12 parts coconut wood chips and sawdust
   - 1 part rye bran
   - 1/8th part gypsum

   These parts were thoroughly mixed by volume with 3 litres of water and equal volumes of 6 litres were placed into 24 off 10 litre sealable growing bags which had been pasteurised by the supplier.
2. The bags were sealed, placed in a pressure cooker and sterilised for 1.5 hours at 120 ^{0}C.
3. To reduce the risk of contamination during the procedure, bulk cereal grain inoculated with the mushroom strain *Pleurotus ostreatus* (White Oyster) was used. After cooling, 60 ml of the inoculated grain was added to each bag. The addition was made working in a laboratory fume-extraction hood. All measuring equipment and mixing implements were sterilised with isopropyl alcohol prior to use.
4. The bags were placed in an environmental chamber at a temperature of 25 ^{0}C, a relative humidity of 75% and an alternating light/dark period of 12 hours. These conditions were considered representative of an average climate on a typical South Pacific Island.
5. After mycelium (fungi) had spread throughout the majority of the growing bags, the bags were split to initiate the primordial fruiting of mushrooms and the environment chambers left open to circulate fresh air and expose the mycelium grown to a temperature of 12 ^{0}C for 24 hours.
6. After 24 hours the chambers were closed and the lights were left on for 24 hours.

4.2 Results

- A white mycelium spawn run began to progress through the growing substrate within two weeks and was mainly complete within four weeks. See Figure 4.
- Seven bags turned a yellowish/brown colour. These were assumed to be contaminated and removed from the environmental chamber.
- Primordial fruiting of small mushroom buttons began to show within a week in all remaining growing bags.
- In the following two weeks, where the first flush of mushrooms was expected, the bags produced few mushrooms and the total yield from all bags was only 230 grams.
- To further initiate fruiting, the chamber’s temperature was decreased to 8 C for a 12 hour period. An additional flush of mushrooms occurred, but the total yield was even lower than the first flush at 185 grams.

4.3 Discussion

Stamets, P. (2000) notes that following the bag production method as detailed in this report, 4 - 5 kilograms of mushrooms could be expected from each bag. The lack of expected mushrooms cultivated in these trials could be attributed to two main causes:

Firstly, as much attention to detail as possible was given to minimise the risk of contamination and although this was clearly visible in the seven bags that were removed, minor contamination in other growing bags could have been responsible for the reduced yields. Additional reading in the mushroom growing literature (Stamets, P. 2000) describes the difficulties in bag growing and that extensive knowledge, experience and very hygienically controlled conditions must exist for a successful outcome.

Secondly, although coconut woodchip has high levels of available sugars (Gibe, 1985), other elements are present that would substantially reduce mushroom yields. Elevated levels of sodium had been reported in a previous ACIAR project (Hopewell, G. 2012) and subsequent chemical analysis in plant-growing medium trials in this current project (see Table 5) showed that coconut wood has high levels of this salt which may be toxic and inhibit the primordial fruiting of mushrooms. These salts are to be expected in coconut wood, which as a halophyte plant incorporates salts taken-up from the coastal region soils where it grows. Washing the coconut chip may leach away some sodium and reduce the level, but with extensive native forest and timber operations on the Islands, other more suitable material for a mushroom growing medium may be readily available.

Figure 4: Mycellium growth through the substrate

Figure 5: Successful mushroom production, but poor yields

5.0 Palm harvest residue for plant growing mediums

This section reports on findings and the results of trials performed to investigate the potential use of coconut palm woodchip as growing mediums for plant production. Commercial scale processing from the proposed rotary peeling of senile coconut palm logs will potentially generate large volumes of harvesting residues. See Section 2.

Results from previous studies (Poulter and Hopewell, 2010), investigating the physical characteristics of coconut harvest residues, indicated chipped and ground residue material had suitable physical properties for use as a plant growing medium. The researchers suggested further trial work on stored nutrients was necessary to determine if coconut woodchip could be used as a plant growing medium. The aims of the studies reported in this section were to determine the nutrient status of the coconut woodchip and examine the materials suitability as a plant growing medium. Pot-scale plant growth trials were conducted using radish and sweetcorn as growth indicators, with the plant material produced chemically analysed for nutrient uptake.

5.1 Method

Three plant growing medium treatments were compared by performing the following method:

1. Two samples of coconut woodchips were screened to a particle size of < 3.0 mm and one sample of a commercially available potting mix manufactured to AS 3743:2003 was used as a plant growing medium.
2. Ten replicate radish and ten sweetcorn seeds per treatment were sown in the pot mediums and their germination rates monitored.
3. During plant growth, to examine and compare plant nutrient uptake, one sample of the coconut woodchip was treated with Hoagland's nutrient solution (Hoagland, D. 1938).
4. After two weeks' growth, plant heights were recorded. The radish was removed and the biomass grown in each treatment weighed.
5. At four weeks the sweet corn plants were removed and leaf samples from each treatment were taken.
6. To determine nutrient availability in the growing mediums, woodchip growing medium was chemically analysed and compared to the AS3743:2003 potting mix.
7. Plants leaf samples from each treatment were sent for laboratory dry-ash analysis.

5.2 Results

- Seed germination rates were consistent with 8 and 9 out of 10 plants in each treatment emerging.
- At two weeks the average sweet-corn plant heights varied between 5.2 cm for those grown in a ground coconut woodchip medium without nutrient solution, to 9.5 cm for plants grown in a commercial potting mix. See Table 4.
- Plants grown in woodchip without additional nutrients grew successfully, but at a slower rate than those given additional fertiliser or grown in the potting mix.
- Chemical analysis comparisons of the woodchip and a commercial potting mix showed the woodchip had elevated levels of many ionic salts. See Table 5.
- Dry-ash leaf analysis indicated the plant had up-taken these elements at high levels. See Table 6.

Table 4: Plant germination and growth results

Plant	Growing medium	Germination rate	Av. biomass g	Av. height cm
Radish	Coconut woodchip	9 out of 10	9	2.1
Radish	Coconut woodchip + nutrients	9 out of 10	18	2.9
Radish	Potting mix - AS3743-2003	9 out of 10	21	3.1
Sweet corn	Coconut woodchip	8 out of 10	-	5.2
Sweet corn	Coconut woodchip + nutrients	9 out of 10	-	6.3
Sweet corn	Potting mix - AS3743-2003	9 out of 10	-	9.5

Table 5: Chemical structure comparison of coconut woodchip with a commercial potting mix manufactured to AS3743:2003

Property / Nutrient		Units	Ground coconut woodchip	Potting Mix	Status
Air-filled Porosity		%	25	*≥13*	*Pass*
Total Water Holding Capacity		%	42	*≥50*	*Fail*
Wettability		min	1m 20s	*≤2*	*Pass*
pH			6.1	*5.3 - 6.5*	*Pass*
Electrical Conductivity		dS/m	5.4	*≤2.2*	*Fail*
Chloride	Cl	mg/L	162	*≤200*	*Pass*
Ammonium	N	mg/L	2.75	*≤100*	*Pass*
NH4 + NO3	N	mg/L	2.96	*≥50*	*Fail*
Phosphorus	P	mg/L	14	*8 to 40*	*Pass*
Potassium	K	mg/L	55	*≥30*	*Pass*
Sulfur	S	mg/L	8	*≥40*	*Fail*
Calcium	Ca	mg/L	28	*≥80*	*Fail*
Magnesium	Mg	mg/L	25	*≥15*	*Pass*
Ca:Mg Ratio		Ratio	1.1	*1.5 to 10*	*Pass*
K:Mg Ratio		Ratio	2.2	*1 to 7*	*Pass*
Sodium	Na	mg/L	511	*≤130*	*Fail*
Iron	Fe	mg/L	1.0	*≥25*	*Fail*
Copper	Cu	mg/L	0.1	*0.4 to 15*	*Fail*
Zinc	Zn	mg/L	1.0	*0.3 to 10*	*Pass*
Manganese	Mn	mg/L	1.0	*1 to 15*	*Pass*
Boron	B	mg/L	0.07	*0.02 to 0.65*	*Pass*

Table 6: Results of sweet corn leaf material dry-ash analyses

Nutrient		Coconut woodchip	Coconut woodchip + nutrients	Potting mix - AS3743-2003
Kjeldahl Nitrogen	%	1.11	4.5	1.1
Phosphorus	%	0.30	0.77	0.22
Potassium	%	2.67	5.38	1.57
Calcium	%	0.45	0.85	0.29
Magnesium	%	0.31	0.49	0.20
Sulphur	%	0.15	0.41	0.17
Manganese	mg/kg	55	130	39
Zinc	mg/kg	47	80	29
Copper	mg/kg	8.6	14	9.8
Iron	mg/kg	53	28	38
Boron	mg/kg	6	54	7

5.3 Discussion

Plant growth rates indicated negligible toxicity was present in the raw woodchip. The leaf analyses showed that although some ionic salts had been incorporated at levels higher than in leaves of plants grown in the potting mix, the level present was not sufficient enough to inhibit plant growth significantly. See Table 4. Plants grown in woodchips only with no additional nutrients demonstrated that nutrients from the woodchips were available and encouragingly, leaf analysis showed levels of uptake were similar to leaves from plants grown in the potting mix and that addition of nutrients to a coconut woodchip medium was not required for plant growth.

This study is the first to examine the nutrient status of coconut woodchip and consider its potential as a plant growing medium. The chemical analyses comparison between a commercially available potting mix and the coconut woodchip (Table 5), indicates some salts are present at unfavourable levels for the woodchip to be used as an independent plant growing medium. However, these results and ones from previous studies suggest there could be some potential, with or without further processing, to use the woodchip material as a soil amendment in broader scale agricultural cropping. This would most likely be implemented post senile palm harvesting and could prove advantageous in coastal regions when coconuts are to be replanted as coconuts are halophyte plants, and therefore highly tolerant of elevated levels of ionic salts in the soil (Ohler, J.G. 1999). Further research is necessary to determine the risk of exacerbating pests and disease that may result from the incorporation raw coconut wood as a soil amendment.

Figure 6: Biomass comparisons in plant growth - coconut woodchip growing medium trials

6.0 Coconut palm harvest residues for biochars

This section reports on findings and the results of trials performed to investigate the potential use of coconut palm harvesting residues as a feedstock for biochar production. Biochar is a form of charcoal attracting worldwide interest for its potential to improve soil health, crop productivity and sequester carbon over the long term.

Biochars are carbon-rich materials and can be added as a soil-conditioning treatment to sequester carbon and potentially maintain or improve soil functions. However, questions remain about the use of biochar in agriculture due to variability of the final product and limited scientific research to-date which has led to a lack of commercial adoption (NSW DPI, 2012). Senile coconut palms are potentially a valuable resource for veneer production in Fiji, Samoa and the Solomon Islands. The harvesting and processing produces residue material (see section 2.0), which can be utilised as a feedstock for biochar production.

One of the objectives of the ACIAR-funded CocoVeneer project is to determine if a useful biochar can be produced locally using residues from harvested coconut palm logs as an end-product feedstock. These studies investigated the potential of pyrolysis to produce coconut wood biochars that could be incorporated with field crops to improve yields. Firstly, to determine the chemical and physical properties of biochars produced from coconut wood, three types of biochar, produced at different temperatures, were produced and analysed. This is reported in Section 6.1. Secondly, to examine the potential to improve field crop yields, biochar was incorporated into field growing trials on Taveuni island, Fiji. This is reported in Section 6.2.

Figure 7: Typical cocowood biochar

6.1 Coconut wood biochar properties trials – Dr Anna Wrobel-Tobiszewska, University of Tasmania.

6.1.1 Introduction

Biochar is made by heating a biomass in an oxygen-limited environment. This can be done in conditions ranging from simple ground pits to sophisticated pyrolysis kilns. This section presents the method and results from analyses of the chemical and physical properties of the biochar end-products, which depend on the type of biomass feedstock used and the conditions, such as temperature and in-kiln residence time during the production. Section 6.3 discusses the results.

6.1.2 Methodology

Residue cores of harvested logs were collected from a Fijian coconut wood milling facility and chipped, dried and fumigated in Fiji before being shipped to Australia in mid-2014. The residue woodchip was then processed into three biochar types by Chaotech Pty Ltd of Brisbane, Queensland, Australia. The following processing methods and examinations were performed:

1. To examine the effect of temperature on the product's chemical and physical properties, material samples were heated with limited oxygen (pyrolysis) in a stationary kiln under three different temperature regimes: 350°C, 500°C, and 750°C.
2. The three biochars produced were sealed in steel drums and sent to Tasmania, Australia for chemical analysis at AgVita Analytical Laboratories.
3. Samples of the biochars were examined by scanning electron microscopy (SEM-EDS) at the University of Tasmania's Central Science Laboratory.

6.1.3 Results

- Chemical analysis of the biochar showed elevated levels of available phosphorous and potassium (Colwell P and K, see Table 7).
- Samples exhibited high pH levels.
- Sodium level was high.
- Cation exchange capacity (CEC, Table 7) was favourably high, particularly for the higher temperature treatment.
- The three biochar processing temperatures generated some differences regarding the availability of macronutrients, micronutrients and liming values.
- A high product porosity was consistent at all three temperatures (Figure 8).

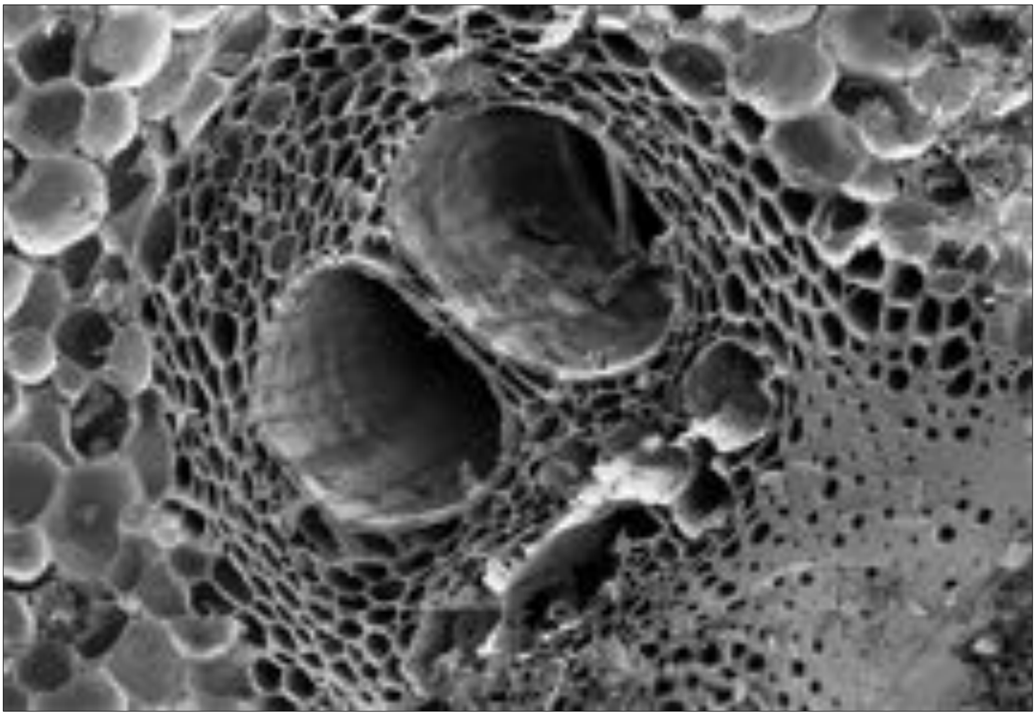

Figure 8: Scanning Electron Microscopy (SEM-EDS) illustrating the high porosity of coconut stem biochar

Table 7: Chemical analysis of coconut biochar produced at three different pyrolysis temperatures. Analysis by AgVita Analytical, Tasmania, Australia.

		Coconut biochar temp 350°C		Coconut biochar temp 500°C		Coconut biochar temp 750°C	
Analyte	***Units***	***Result***	***Status***	***Result***	***Status***	***Result***	***Status***
pH		8.49	very high	9.02	very high	10.61	very high
EC	ds/m	2.01	moderate	2.24	moderate	3.96	high
Organic Carbon	%	9.38	high	8.48	high	6.5	high
Sodium	meq/100g	47.83	very high	68.24	very high	130.8	very high
Aluminium	meq/100g	0.01	very low	0.01	very low	0	very low
Phosphorus (Colwell)	ppm	181	very high	277	very high	242	very high
Potassium (Colwell)	ppm	1297	very high	1388	very high	2096	very high
Boron	ppm	0.43	low	0.42	low	0.45	low
Copper	ppm	0.07	low	0.05	low	0.09	low
Iron	ppm	0.78	low	0.5	low	1.55	low
Zinc	ppm	0.18	low	0.31	low	2.01	very high
Cation Exchange (CEC)	meq/100g	51.6	very high	76.1	very high	142	very high
Calcium (% CEC)	%	3.55	very low	6.62	very low	3.94	very low
Magnesium (% CEC)	%	1.4	very low	0.65	very low	0.88	very low
Potassium (% CEC)	%	2.35	low	2.74	low	3.07	low
Sodium (% CEC)	%	92.7		89.7		92.1	
Total Carbon	%	69.2		80.1		85.9	
Toatal Nitrogen	%	0.53		0.49		0.66	

6.2 Coconut wood biochar field trials - Geoff Dean, University of Tasmania.

6.2.1 Introduction

This section presents the method and results of a field trial of biochar on Taveuni, Fiji conducted by Geoff Dean of the University of Tasmania. This examined the potential of coconut residue biochar to alleviate soil health problems. Results were evaluated by measuring changes in the yield of taro produced after the addition of coconut biochar to the soil. Section 6.3 discusses the results.

On the island of Taveuni, Fiji, the predominant crop grown is taro, which supplies up to 70% of the taro exported to Pacific Island communities living in Australia and New Zealand. Continuous cropping of taro and kava on the island has led to reduced crop yields and increased incidence of corm rots and insect pests resulting in high reject rates. Over-cropping in general has resulted in reduced soil fertility and organic matter levels. Therefore, farmers perceive that the soil is worn out and new cropping ground must be found.

The research reported in Section 6.1 above, has shown that biochar has a high cation exchange capacity that increases levels of exchangeable cations in the soil, thereby reducing the leaching of nutrients and potentially lowering fertiliser requirements. Due to the highly porous nature and large surface area of biochar, adsorption capacity is very high, resulting in a high water holding capacity. See Figure 8. The high porosity also provides habitat for soil microbes that contribute to both unlocking of soil nutrients and improved soil aggregation.

6.2.2 Method

1. As well as testing the three coconut wood biochar products reported in section 6.1, these trials also included comparison treatments of locally produced biochar from two feed-stock sources: low density coconut wood and guava wood (an aggressive weed in parts of the Pacific). Pyrolysis was conducted in controlled kiln conditions at a temperature of 500 ^{0}C. See Table 8.
2. Priming of biochar with nutrients and beneficial organisms is generally regarded as improving the timeliness of the biochar effects, and reducing the potential for fixing soil nutrients. Primed treatments consisted of biochar mixed with fishmeal; soft rock phosphate fortified with additional potassium; and small amounts of molasses; compost and water.
3. The different biochars, incorporation methods, and rates of application resulted in sixteen treatments, which were all primed except for the control treatments. See Table 8.
4. Due to extreme drought conditions during the trial period, to prevent losing the trial it was necessary to apply irrigation water by hand.

6.2.3 Results

- A mean corm weight of 1247 g was measured across all treatments.
- There were no statistically significant differences in mean corm weight between biochar treatments and no consistent effects of initial feedstock, pyrolysis temperature, rate of biochar and priming.

- The spread and incorporated primed biochar treatments (Treatments 14 and 15) tended to outperform the controls un-primed and treatments applied in the hole (see % weight of control – Table 8).
- Only 2% of corms were rejected from having a weight of less than 600 g and these were not aligned with any particular treatment.
- There was very little noticeable corm rot (0.5%) and no incidence of mealybugs, a commonly found plant pest of economic significance on taro grown in the South Pacific Islands. Both of these pests are indicators of poor soil health.

Figure 9: BiocharTaro-corm field crop trial Taveuni, Fiji

Table 8: Biochar treatments applied to a taro crop in Taveuni, Fiji

Treatment number	Feedstock material	Pyrolysis temp degs. C	Application method	Biochar rate (g)	Units	Primed Y/N	Taro corm weight (g)	% weight of control
1 (control)	NA	NA	NA	0	NA	NA	1291	100
2	NA	NA	applied to hole	0	NA	Y	1205	93
3	cnut- Australia	350	applied to hole	100	g/hole	Y	1257	97
4	cnut- Australia	500	applied to hole	100	g/hole	Y	1280	99
5	cnut- Australia	750	applied to hole	100	g/hole	Y	1208	94
6	cnut-Taveuni	500	applied to hole	50	g/hole	Y	1189	92
7	cnut-Taveuni	500	applied to hole	100	g/hole	Y	1154	89
8	cnut-Taveuni	500	applied to hole	200	g/hole	Y	1256	97
9	cnut-Taveuni	500	applied to hole	100	g/hole	N	1209	94
10	guava-Taveuni	500	applied to hole	100	g/hole	Y	1202	93
11	guava-Taveuni	500	applied to hole	200	g/hole	Y	1275	99
12	guava-Taveuni	500	applied to hole	100	g/hole	N	1220	95
13 (control)	NA	NA	NA	0	NA	NA	1293	100
14	cnut-Taveuni	500	spread, incorporated	10	t/ha	Y	1349	105
15	guava-Taveuni	500	spread, incorporated	10	t/ha	Y	1308	101
16	guava-Taveuni	500	spread, incorporated	10	t/ha	N	1253	97

6.3 Discussion

Factoring in the low rainfall during the trial's growing season and the average corm size recorded elsewhere on the island, the mean corm weight of 1247 g measured across all treatments was considered as exceptionally good. However, the irrigation water applied could have potentially masked any beneficial water holding properties of the biochar.

In the biochar properties study, elevated levels of phosphorous and potassium in the biochar could result in release of these elements to the growing medium, consequently increasing their availability for plants. High cation exchange capacity indicated a strong ability of biochar to retain essential nutrients and improve overall soil quality. The elevated sodium level can be considered unfavourable and could possibly antagonise the release of other elements. However, the effect of biochar on soil nutrient status depends on both the biochar's properties and soil type. The soil sodium levels at the trial site were relatively low at 31 mg/kg. A high porosity product is considered very beneficial in promoting microorganism-dependent soil processes and in water retention.

Due to the trial being conducted largely through farmer support as part of a commercial operation close to optimal nutrition was provided and consequently the potential to reduce fertiliser rates could not be assessed. However, it is not unexpected that under close to non-limiting conditions biochar will have less beneficial effect. While it is generally believed that declining taro yields can be attributed to decreased soil fertility and loss of organic matter, a soil test at the trial site showed 4.5% organic carbon which may have masked any nutrient exchange benefits from biochar treatments. In contrast, labile C (the carbon component which is more readily available) was low (0.3%) compared with other areas tested. Therefore, the inert nature of additional carbon supplied in biochar may be of little value, due to existing adequate levels of carbon present. However, yield response tended to be improved when biochar was primed and spread broad-scale before sowing. This may be a quantity effect as the amount of biochar applied to these plots was 10 fold higher than the standard 100g applied in each taro hole.

Figure 10: Incorporating broad-scale spread biochar on Taveuni, Fiji for taro field trial

7.0 Coconut palm harvest residues for composting

This section reports on findings and the results of trials performed to investigate the potential use of coconut palm harvesting residues as a feedstock compost manufacturing. Commercial landscape product manufacturers contacted during these trials suggested coconut woodchip could be a suitable feedstock material for composting into a nutrient rich medium and used for improving agricultural crop yields.

The aim of the study reported here was to establish if coconut woodchip residue material is a potential suitable feedstock material for composting. A garden scale composting technique was adopted to produce 100 litres of compost from a coconut woodchip that was previously supplied from Fiji. See Figure 12. After the compost was produced, a sample was sent for laboratory analysis and a plant growth toxicity test of the compost was performed. Following this test, a plant growth trial with a randomised complete block of 7 treatments x 5 replicates per treatment design was conducted. The growth mediums used in the treatments included the coconut wood compost produced, a local (Southeast Tasmania) sandy loam soil, coconut biochar produced during this project, and a commercially available compost. See http://munash.com.au/retail-garden/revitalize/revitalize-specifications/. The soil was chemically analysed at Allison laboratories in Hobart, Tasmania, using methods developed by Rayment and Lyons, 2011. The analysis showed the soil had the nutrient properties consistent with a sandy-loam type. The material preparation and tests performed are described below.

7.1 Methods

Composting the coconut wood chip

1. 80 litres of coconut woodchip, 20 litres of green garden waste grass clippings and 10 litres of organic nitrogen fertiliser (fish-meal) were placed in a 135 litre garden compost tumbler. See Figure 11.
2. The material was mixed with approximately 20 litres of water.
3. The compost tumbler was placed in a hot-house environment with a constant temperature of 25 ^{0}C, which was considered representative of average temperatures in the South Pacific Islands. To maintain aerobic bacterial activity, the tumbler was rotated daily for 12 weeks.

Coconut wood compost sweetcorn plant growth trial

1. To obtain a result more comparable to broader scale application of growing mediums 35 off x 4 litre pots were steam-sterilised and prepared as follows:
   - Treatment 1. Soil 3.6 L /pot.
   - Treatment 2. Soil 3.6 L + coconut wood biochar (cwb) 450 ml /pot.
   - Treatment 3. Soil 3.6 L + coconut wood compost 126 ml /pot.
   - Treatment 4. Soil 3.6 L + commercial compost 126 ml /pot.
   - Treatment 5. Soil 3.6 L + coconut wood compost 126 ml /pot and cwb 450 ml /pot.
   - Treatment 6. Soil 3.6 L + coconut wood compost 126 ml /pot and cwb 450 ml /pot + Urea 0.56 g /pot.

   The treatment growing medium rates are the equivalent of 22 L /5 m^2 (top-dressed) for compost (recommended in the organic compost manufacturers specifications), 12% by volume for the biochar (Grayson Australia, 2014) and urea applied at 90 kg /ha top-dressed (NSW DPI, 2014).

2. To assist in priming (activating) the biochar, the pots were left to stand under glasshouse overhead sprinkler irrigation at a rate of 4 x 19 mm /hour irrigations per day, of 4 minutes each for 4 weeks. After this period, to prevent compaction and provide good root respiration, individual pots were remixed just prior to planting, representative of field harrowing prior to seed planting.
3. A germination test was performed to test the viability of sweet corn (*Zea mays*) seed.
4. Five seeds were sown into each pot at a depth of 10 mm.
5. The pots were placed on a glasshouse bench in a randomised order, one pot per treatment in each of 5 replicates. 5.0 mm of overhead spray irrigation were applied in 24 hours daily.
6. After 10 days the germination rates in each pot were recorded.
7. After 63 days post sowing, the plants were removed and dried at 40 degrees C for 48 hours, and the leaf and stem biomass of each plant was recorded.

Coconut wood compost pea plant growth trial

1. To further test the growth response seen in the sweet corn, a monocotyledon plant, a smaller-scale three treatment trial was performed using a dicotyledonous pea plant. The three treatments were as follows:
   - Treatment 1. Soil 3 1.5 L /pot.
   - Treatment 2. Soil 1.5 L + coconut wood compost @ 126 ml /4 L/pot.
   - Treatment 3. 1.5 L /pot, coconut wood compost and vermiculite 50:50 ratio /pot.
2. Pea seeds were soaked overnight and sown into 15 cm (1.5L) plastic pots.
   Two seeds per pot were sown. Following germination, seedlings were thinned to one plant per pot.
3. The trial was conducted in the glasshouse on benches, receiving overhead sprinkler irrigation.
4. After 42 days post sowing the plants were removed and dried at 40 degrees C for 48 hours, and the leaf and stem biomass of each plant was recorded.

7.2 Results

Table 9: Chemical analysis of the garden-scale tumbler produced coconut wood compost to Australian Standard AS3743:2003. Analysis by the AgVita Analytical, Tasmania. Australia.

Aust. Std. AS3743:2003	Nutrient	Units	Value	Acceptable Range
Moisture Content		%	74	*>40*
Air-filled Porosity		%	..	*≥13*
Total Water Holding Capacity		%	..	*≥40*
Wettability		min	..	*≤5*
pH (1:1.5)		pH units	7.3	*5.3 to 6.5*
Electrical Conductivity (1:1.5)		dS/m	1.62	*≤2.2*
Chloride	Cl	mg/L	98	*≤200*
Ammonium	N	mg/L	28.12	*≤100*
NH4 + NO3	N	mg/L	3.8	*..*
Nitrogen Drawdown Index		NDI	..	*≥0.2*
Toxicity		mm	..	*≥70*
Phosphorus	P	mg/L	424	*..*
Potassium	K	mg/L	824	*≥30*
Sulphur	S	mg/L	86	*..*
Calcium	Ca	mg/L	568	*≥50*
Magnesium	Mg	mg/L	214	*≥15*
Ca:Mg Ratio		Ratio	2.7	*1.5 to 10*
K:Mg Ratio		Ratio	3.9	*1 to 7*
Sodium	Na	mg/L	195	*≤130*
Iron	Fe	mg/L	10.3	*≥25*
Copper	Cu	mg/L	1.96	*0.4 to 15*
Zinc	Zn	mg/L	22.8	*0.3 to 10*
Manganese	Mn	mg/L	14	*1 to 15*
Boron	B	mg/L	1.14	*0.02 to 0.65*

Table 10: Pot trial results of sweet corn leaf and stem biomass by weight at 63 days.

Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g
1	1	13.86	**2**	1	13.31	**3**	1	14.31	**4**	1	10.2	**5**	1	51.33	**6**	1	24.94
1	2	9.91	**2**	2	10.26	**3**	2	12.06	**4**	2	11.36	**5**	2	15.94	**6**	2	13.37
1	3	10.44	**2**	3	6.69	**3**	3	25.66	**4**	3	12.81	**5**	3	8.09	**6**	3	12.05
1	4	18.24	**2**	4	16.89	**3**	4	17.76	**4**	4	10.74	**5**	4	21.58	**6**	4	19.66
1	5	10.21	**2**	5	15.47	**3**	5	14.05	**4**	5	10.61	**5**	5	13.71	**6**	5	15.1
	Mean	12.532		Mean	12.524		Mean	16.768		Mean	11.144		Mean	22.13		Mean	17.024

Trt.= Treatment, Rep = Replicate, Wt.= Weight

The observed seed germination rates in both sweet corn and pea trials were 100%. By day ten in each trial, all plants in each pot had germinated, which indicated reliable seed stock and that no growing treatment used was toxic.

Table 10 shows favourable growth results were observed for sweet corn grown in treatments 3 and 5 containing the coconut wood compost. The mean growth response for plants grown in coconut wood compost exceeded that of the plants grown in the same soil and a commercially available organic compost. A Tukey's HSD test of pooled data showed the treatments were not significantly different.

Table 11: Coconut wood compost pot trials peas leaf and stem biomass leaf by weight at 42 days.

Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g	Trt.	Rep.	Wt. g
1	1	1.47	**2**	1	5.72	**3**	1	0.82
1	2	1.44	**2**	2	6	**3**	2	0.96
1	3	2.2	**2**	3	5.2	**3**	3	0.82
1	4	2.46	**2**	4	3.85	**3**	4	0.55
1	5	1.77	**2**	5	3.88	**3**	5	0.61
	Mean	1.868		Mean	4.93		Mean	0.752

Trt.= Treatment, Rep = Replicate, Wt.= Weight

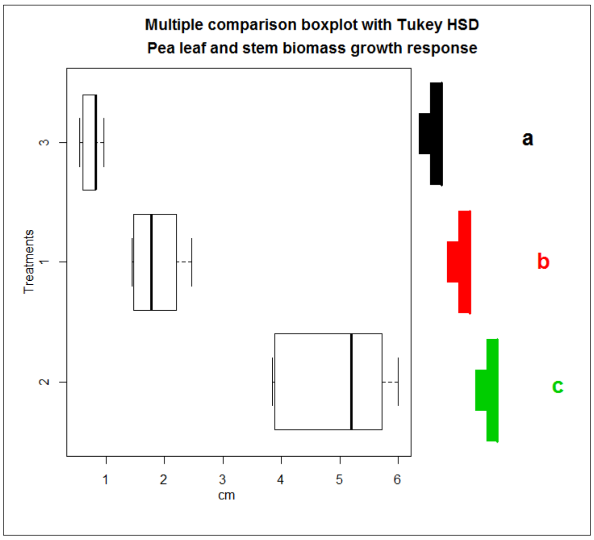

Figure 11: Tukey Honestly Significant Difference Test (HSD) of treatment means.

Table 11 shows the favourable means growth results for peas grown in treatment 2 containing the coconut wood compost, when compared to soil only in treatment 1 and to a mix of coconut compost and vermiculite, which would provide only nutrients available from the coconut compost. The mean growth response for plants grown in coconut wood compost far exceeded that of the plants grown in the same soil only and a Tukey Honestly Significant Difference Test (Tukey's HSD) demonstrated the treatment growth responses were significantly different.

7.3 Discussion

The garden scale compost produced indicates a usable cocowood compost could potentially be produced at a larger commercial windrow scale. The results observed in these small-scale pot trials also indicate a favourable growth response could be expected if crop plants were sown into a soil amended with the addition of cocowood compost. Compared to earlier trials using unprocessed coconut wood chip as a direct growing medium, the composting process substantially improved nutrient availability and has reduced potentially toxic salt levels, as shown in Table 9, most likely due to the leaching effect of water added during compost production. The contrary Tukey Honestly Significance Difference test results between the sweet corn and pea growth responses indicates larger trial studies are required to examine the growth response of plants favoured for either rehabilitation, or cropping of an area after senile palm harvesting.

If compost were produced on a larger-scale it could be particularly beneficial in many Pacific Islands, as the modern approach of intensified land-use means more products are removed from the land and therefore the export of nutrients is high.

Initial inquiries with compost makers and potential uses of the compost in the Fijian Islands expressed concern about the potential spread of Coconut Rhinoceros Beetle (*Oryctes rhinoceros*). However, the adult beetle feeds only on green frond material and if eggs have been laid prior to windrow preparation, it takes longer for rhinoceros beetle larvae to develop than it takes to make aerobic compost, so properly maintained compost should not serve as a source of rhinoceros beetles (American Samoa Community College Community & Natural Resources Cooperative Research & Extension. 2005).

Figure 12: A coconut compost produced after 12 weeks

Figure 13: Left- coconut compost incorporated with soil, compared to a commercially available compost in sweet corn growth trials.

Figure 14: Right- coconut compost incorporated with soil, compared to soil and compost with vermiculite in pea growth trials.

8.0 Coconut Palm harvest residues - Conclusions

This document has identified and highlighted the particular importance of planning for the use of harvest residues, which must coincide with planned harvesting activities. Given the variety of post-harvest residue material as root-bowl, low-density palm stem, general wood trash and green frond and the potential volume of residue material, which will be available should senile coconut estates be replaced, it is unlikely one particular type of by-product will address need to remove the residue.

The use of coconut wood chips to provide a direct growing medium for either mushrooms (Section 4) or as plant growing mediums (Section 5) was largely unsuccessful. Thorough investigation was made of the mechanical and chemical properties of raw woodchip and reasons for the unsuccessful attempts at using the material have been presented.

The use of coconut wood biochar to improve crop yields (Section 6) proved inconclusive, which is in common with other research investigating the use of biochar in horticulture (NSW DPI, 2012).The trend of favourable yield response from biochar priming and broad-scale spreading (Section 6) would suggest more nutrients were made available to the plant when the biochar was primed and spread, rather than incorporated in a concentrated form in the planting hole. Clearly more research is required to investigate optimal biochar application methods. It is now generally recognised that the benefits of biochar are long term (NSW DPI, 2012) and therefore in the study presented, there may have been insufficient time for the benefits of incorporation into the soil to be expressed as favourable growth responses.

The use of coconut palm residues for fuel, particularly for industrial use and electricity generation bodes well, provided demand exits and transportation costs are acceptable, and that capital investment is available for the necessary infrastructure. The model that demonstrates this is feasible presently exists in Labasa, Vanua Levu, Fiji (Section 3) and additional feedstock material from coconut harvesting residues could be used to investigate either its expansion, or the deployment of new greenfield power generation sites in other South Pacific countries.

The composting of harvest residues for soil amendments (Section 7) appeared to be the most cost effective means of utilising coconut palm harvesting residues. Little additional investment is required to produce a product which would be directly beneficial to the local communities managing the land the plantations are on. The expected elevated salt levels observed in raw coconut woodchip samples during these studies were substantially reduced in the small-scale composting trial, most likely due to leaching from wetting and other biochemical reactions occurring during the composting procedure. This would also occur at the larger windrow paddock scale. Composting is a largely forgiving process that can occur over a wide range of conditions. As such there is no clearly defined time to produce finished compost and a lot depends on the feedstock materials, the climate during composting, and maintaining the windrow at an optimum condition for aerobic bacterial activity.

Composting of organic wastes is an environmentally sound method of converting material generally regarded as waste into a product that can be used in agriculture, horticulture, landscaping and the remediation of contaminated sites. An increased tendency for intercropping and/or mixed farming operations in the Pacific Islands means more products are removed from the land and therefore the export of nutrients is high. The composting of coconut wood residues would provide the opportunity to address that nutrient loss and potentially increase crop productivity, and further opportunities for product sales could exist.

Evidence from previous studies, assessment of the material residues and discussion with Australian commercial composters during this project, suggests that coconut woodchip is suitable for composting into a nutrient rich medium that can be readily used for improving future crop yields or for landscaping. Additionally, the Pacific Island region has an appropriate climate for cost-effective composting. Larger-scale trials are now recommended to examine the feasibility of this activity using coconut palm harvest residue material as a feedstock.

9.0 Acknowledgements

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