Research Note: Coconut biochar: Taveuni field trail

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Introduction

The ACIAR project, FST/2009/062, has demonstrated the feasibility of converting senile coconut palms into high quality laminated flooring, veneer and other high value end products. However, the question still remains –how to use the significant quantity of low density cocowood left over as a by-product? Options include producing compost and biochar as soil amendments or utilising as a growing media for industries such as mushroom production. This study examined the potential of biochar produced from cocowood to alleviate soil health problems.

On the island of Taveuni, Fiji, the predominant crop is taro supplying up to 70% of the taro exports to Pacific Islander 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 has resulted in reduced soil fertility and organic matter (OM) levels and the perception of farmers is that the soil is worn out and new cropping ground must be found. As a consequence increased areas of forest are being cut and Taveuni has some of the highest forest clearance rates in Fiji. With the benefits of organic amendments, rotations and other agronomic practices, soil “health” can be improved in these areas and farmers can continue to crop on “old ground”.

Many research studies have demonstrated the value of application of biochar in improving soil structure, chemistry and biology. Through a high cation exchange capacity (CEC) levels of exchangeable cations in the soil are increased as well as reduced leaching of nutrients and lower fertiliser requirements. Due to the extremely porous nature and large surface area, adsorption capacity is very high resulting in a high water holding capacity. The large number of pores also provides habitat for soil biology which contribute to both unlocking of soil nutrients and improved soil aggregation.

The characteristics of biochar vary due to a number of factors such as type of feedstock and production temperature. During pyrolysis, regulating the temperature will alter biochar characteristics with higher temperatures resulting in an increase in pH and absorption capacity and generally CEC. As increased CEC is a critical component of inherent soil fertility, a further aspect of this study was to pyrolize cocowood at a range of temperatures to determine whether there are changes in biochar characteristics that are beneficial to soil health. To ensure sufficiently accurate temperature control during pyrolysis it was necessary to send feedstock from Fiji to Australia for kilning.

With few tractors on Taveuni and often rocky and hilly terrain, hand planting of taro is standard practice. Prior to planting, basal fertiliser is applied to each hole and application of biochar using a similar practice is therefore justified. This also allows the use of relatively small amounts of biochar, an important consideration in this study with the considerable expense of shipping material to and from Australia. Consequently the majority of biochar treatments in this study were applied to the hole prior to planting. However, most biochar research conducted to date has used large amounts of biochar e.g. 10-20 t/ha broadcast and then incorporated with machinery. Thus as a comparison similar broad scale treatments were also included with biochar spread by hand and incorporated by rotary hoeing. With the latter methodology there was also a greater opportunity to demonstrate any potential yield benefits from biochar. The downside was a significantly greater quantity of biochar required in each plot and this was only economically feasible for locally produced biochar. Thus the study also included comparison treatments of locally produced biochar. This was from two sources: low density cocowood and guava wood (an aggressive weed in parts of the Pacific). As there was sufficient quantity of local biochar an additional trial was included with different rates of biochar applied in the hole (see Table 1 for treatment list).

Priming of biochar with nutrients and beneficial organisms is generally regarded as improving the timeliness of biochar effects and reducing the potential for fixing soil nutrients. All treatments were thus primed apart from controls for each of the two application methods, in-hole and machine incorporation (Table 1; not-primed). Treatments with the equivalent rate of nutrients in the primer mix but with no applied biochar completed the treatment list.

The aim of this study was thus primarily to evaluate the potential of biochar produced from low density and upper stem cocowood as a means of improving soil productivity, as measured by the yield of taro. In addition a series of other biochar treatments were included:

- Effect of different feedstock on biochar: guava compared with cocowood
- Comparison of in-hole application with broadcast and machine incorporation
- Evaluating the effect of pyrolysis temperature on CEC and other parameters

- Effect of increasing rate of biochar for in-hole application
- Effect of priming on the efficacy of biochar

Table 1. Biochar treatments applied and effect on taro corm weights in (g) and as a percentage of the control at "Vunivasa", Taveuni in 2014-15.

Biochar treatments varied for feedstock (coconut or guava produced in Australia or Taveuni), pyrolysis temperature, incorporation method, rate applied and whether primed with nutrients.

Trt	Feedstock	Temp (^{0}C)	Incorporation method	Rate		Primed	Corm wt (g)	% of cntl
1	None (nil)	-	applied to hole	0	g/hole	**-**	1291	100
2	none	-	applied to hole	0	g/hole	=y	1205	93
3	cnut-Aus	**350**	applied to hole	100	g/hole	y	1257	97
4	cnut-Aus	**500**	applied to hole	100	g/hole	y	1280	99
5	cnut-Aus	**750**	applied to hole	100	g/hole	y	1208	94
6	cnut-Tav	500	applied to hole	50	g/hole	y	1189	92
7	cnut-Tav	500	applied to hole	100	g/hole	y	1154	89
8	cnut-Tav	500	applied to hole	200	g/hole	y	1256	97
9	cnut-Tav	500	applied to hole	100	g/hole	**no**	1209	94
10	guava-Tav	500	applied to hole	100	g/hole	y	1202	93
11	guava-Tav	500	applied to hole	200	g/hole	y	1275	99
12	guava-Tav	500	applied to hole	100	g/hole	**no**	1220	95
13	none	-	spread, incorp	0	t/ha	=y	1293	100
14	cnut-Tav	500	spread, incorp	10	t/ha	y	1349	105
15	guava-Tav	500	spread, incorp	10	t/ha	y	1308	101
16	guava-Tav	500	spread, incorp	10	t/ha	**no**	1253	97

Methods

Biochar pyrolysis and analyses: Pyrolysis was undertaken in Australia for treatments requiring greater temperature control and locally in Taveuni for producing larger quantities of biochar. Prior to shipping to Australia, coconut stems from Sigatoka, Viti Levu were chipped and air dried. Approximately 400 kg of chipped cocowood was shipped to Chaotech Pty. Ltd, Brisbane, Queensland for controlled pyrolysis at three temperatures: 350, 500 and 750^{0}C. A mean of 17 kg (dry weight) of each of the three treatments was transported back to Fiji.

Figure 1*:* Cocowood chips prior to pyrolysis in Australia.

Figure 2*:* Cocowood chips after pyrolysis at Chaotech Pty. Ltd, Brisbane.

For the Taveuni produced biochar, coconut stems were collected locally and the outer higher density wood removed with a chainsaw. The inner core material was cut into 75 mm square section blocks to enable chipping. Due to the high moisture content and insufficient time for air drying the woodchips required pre-drying in a kiln before pyrolysis at 500^{0}C using a Carbon Gold SuperChar Mk II unit.

Chemical analyses were undertaken on the three batches of cocowood biochar at AgVita laboratory, Tasmania (see Appendix 1). Of note the high CEC of the biochar should be beneficial for improving soil CEC and this characteristic increased with higher pyrolysis temperature. Higher pH, EC and exchangeable cations with increasing pyrolysis temperature are a reflection of increasing ash content.

Biochar processing and priming

To reduce particle size and improve timeliness in effects of biochar the different batches of biochar were crushed in a modified large food grinder so that the majority of particle sizes were less than 2 mm. Coconut biochar tended to be lighter and visually more powdery than biochar produced from guava.

All biochar treatments to be primed were mixed with water, fishmeal (NPK analysis: 8:1:1), soft rock phosphate fortified with additional K (0:10:6 + trace elements), molasses (0:0:1); and a small amount of compost (2:1:0) at a percentage ratio of w/w: 46.8 : 46.8 : 3.5 : 1.2 : 1.2 : 0.5 respectively. Each batch was mixed thoroughly in a cement mixer and then "primed" in plastic drums for 32 days.

Figure 3*:* Crushing biochar in a modified food grinder and the crushed cocowood biochar.

Field trial

The field trial was conducted at "Vunivasa", north-east Taveuni (16^{0} 46' 55" S, 179^{0} 49' 57" W) on a mollisol soil with parent material of volcanic origin. The soils in this area are the oldest on the island, around 50 000 years and are well weathered with low levels of available P and exchangeable Ca, K and Mg and high exchangeable Al and H. The trial area was in short term fallow having previously been planted with pineapples for four years. The field had a history of regular cropping. The experiment was a split plot design with the three pyrolysis temperature treatments blocked together in each of the four replicates. The plot size was 4m x 6m i.e. 24 taro plants per plot.

Figure 4*:* Broadcasting and incorporating biochar treatments at trial site, "Vunivasa", Taveuni.

Broad-scale biochar treatments were spread by hand in the designated plots and biochar incorporated using a tractor mounted rotary hoe during ground preparation of all plots. The trial was planted 7 days later on 13th August 2014. Planting holes were dug by hand with digging forks to a depth of 20-25 cm at a spacing of 1m x 1m (standard practice) and in-hole biochar treatments applied and mixed with a fork. A multi-nutrient fertiliser (8:10:10 + Zn, Cu and B) and soft rock phosphate (0:11:6 + Zn, Cu and B) were both applied at a rate of 25g in each hole. Taro planting material was the standard taro export variety "Tausala ni Samoa". Suckers were initially graded for uniformity and then further blocked by size into the four replicates. The planting process adequately mixed the fertiliser with soil in the hole.A further topdressing of 8:10:10 (25g/plant) was applied in-crop. Weeds were sprayed as necessary. Due to the exceptionally dry conditions the trial was irrigated twice.

The trial was harvested on 19th Feb 2015. Corms were individually weighed and scored for corm rot (likely *Pythium* and *Erwinia* spp) and mealy bugs (probably *Paraputo* sp).

Figure 5*:* Harvesting biochar taro trial at "Vunivasa", Taveuni.

Figure 6*:* Weighing and sorting taro corms at biochar trial, "Vunivasa", Taveuni

Results and Discussion

Given the very low rainfall, particularly early in the growing season, the mean corm weight of 1247 g was exceptionally good. A dryland fertiliser trial planted one km away with a similar planting date grew poorly and was abandoned. The difference in result can be attributed to good size planting material and in particular, irrigation.

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. Mean corm weights were high with only 2% rejects (less than 600g) and these were not aligned with any particular treatments. There was also very little corm rot (0.5%) and no incidence of mealybugs.

With biochar able to hold up to five times it's mass in water one of the reported benefits of biochar is increased water holding capacity. Due to extreme drought conditions the trial was irrigated but given the high corm weights across all treatments it seems likely that this may have masked the potential water holding effects of the biochar. A number of studies have shown the potential for reduced fertiliser when applied with biochar. However as the trial was conducted largely through farmer support as part of a commercial operation, optimal nutrition was provided. It is not unexpected that under close to non-limiting conditions biochar may have less effect. Although there were not significant results, there was a trend towards increased yield from application of biochar in two other farmer trials that were severely drought affected in the 2014 dry season.

While it is generally perceived that declining taro yields are due to decreased soil fertility and loss of OM, recent soil tests taken around the island on cropping soils show that OM levels are remarkably high with most OM levels over 15% (total carbon 8%). This can be attributed to the mineralogy of the commonly Andisol (volcanic) soils containing inherently high levels of amorphous Fe and Al sesquioxides which bind with OM so that it is not mineralized. The OM at the trial site soil was considerably lower than this (4.5%) but none-the-less a value of this level is more than adequate thus probably masking nutrient exchange benefits from biochar treatments. In contrast, labile C on this farm can be very low (e.g. 0.3%) and in a nearby field trial there were large responses to application of a fish waste organic amendment. It is possible that the inert nature of additional carbon supplied in biochar is of little value due to the existing adequate levels of total carbon in the soil. Supply of more available carbon as a food source for soil biology may therefore be of greater benefit.

Finally, it is also generally recognized that the benefits of biochar are long term and thus there may have been insufficient time for the benefits to show. CEC in particular increases up to orders of magnitude as the biochar ages or matures. Marker posts have been placed at the corners of the trial to enable a further trial to be conducted in 2017 or 2018 when the next taro crop is grown.

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This research note is part of the ACIAR-funded CocoVeneer 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, the Queensland Department of Agriculture, and Fisheries (DAFF), the Secretariat of the Pacific Community (SPC), the Fiji Department of Forests; Forest Research and Development Section, Forestry Division, Ministry of Natural Resources and Environment, Samoa; Ministry of Forestry, the Solomon Islands, and industry in Australia and Pacific Islands. The project supports economic development in Fiji, Samoa and the Solomon Islands. The project 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.

Appendix 1

Table 1: Chemical analysis of the coconut Biochar product at three different production temperatures. Analysis and report by the AgVita Analytical, Tasmania. Australia.

		350 C		500 C		750 C	
Analyte	**Units**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**
pH ($CaCl_2$)	-	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 (NH_4Cl)	meq/100g	47.83	very high	68.24	very high	130.8	very high
Aluminium (KCl)	meq/100g	0.01	very low	0.01	very low	0	very low
Colwell P	ppm	181	very high	277	very high	242	very high
Colwell K	ppm	1296.86	very high	1388.19	very high	2095.81	very high
Boron (hot water)	ppm	0.43	low	0.42	low	0.45	low
Copper (DTPA)	ppm	0.07	low	0.05	low	0.09	low
Iron (DTPA)	ppm	0.78	low	0.5	low	1.55	low
Zinc (DTPA)	ppm	0.18	low	0.31	low	2.01	very high
CECe	meq/100g	51.6	very high	76.08	very high	142.01	very high
Calcium (% CEC)	%	3.55	very low	6.62	very low	3.94	very low
Magnesium (% CEC)	%	1.4	very low	0.95	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	%	69.24		80.06		85.92	
Total Nitrogen	%	0.53		0.49		0.66	