Australian Government
Australian Centre for International Agricultural Research

Australian Aid

TADEP+ Collaborative Research Grant
Final Report

This Collaborative Research Grant funding is designed to enable newly-identified opportunities for cross project collaboration, cross-project capacity building, new activities that could directly address high-level targets of the Australian aid program and in doing so, enhance the value of the Program beyond the sum of its five component projects.

This reporting template is provided to capture the key activities, outputs, impacts and learnings from the Collaborative Research Grant project. This report will be uploaded to the TADEP+ website and circulated as part of the TADEP+ Updates.

Summary (as per application)	
Title	**Organic wastes or wasted opportunities?**
Goal	This project aims to reduce soil nutrient depletion and increase the use of low cost and low technology soil supplements in PNG
Summary	Soil nutrient depletion is a major issue threatening food security. Organic waste (e.g. food scraps, cocoa pods and canarium waste in the galip factory) is usually burnt causing environmental pollution. Such organic waste can be turned to compost at little or no cost. This compost can be used for farm improvement and/or sold. This project provided training for composting to different audiences including university students, agricultural scientists and selected small-scale farmers to ensure economic, soil and wider community benefits.
Number and title of projects with which this application was associated	1. FST/2014/099: Enhancing private sector-led development of the canarium industry in PNG 2. ASEM/2014/095: Improving opportunities for economic development for women smallholders in rural PNG 3. SMCN/2014/048: Optimising soil management and health in Papua New Guinea integrated cocoa farming systems

Partner organisations	University of the Sunshine Coast University of Canberra University of Sydney National Agriculture Research Institute (NARI) PNG University of Natural Resources and Environment (UNRE)
Program objectives this activity addressed	☐ Private sector-led development ☒ Agricultural productivity, quality and value ☒ Access to market and value chains ☒ Gender equality and women's empowerment ☒ Individual and institutional capacity building
If this activity specifically addressed higher level targets of the Australian aid program, which ones?	☒ Engaging the private sector ☒ Empowering women and girls

Executive summary

This project sought to use galip factory waste to produce galip compost. The project trialled a range of application rates in two annual crops — corn and sweetpotato.

The key achievements included:

- **Evidence that galip compost improved soil fertility.** Galip compost was applied in both corn and sweetpotato crops. Soil amended by galip compost at the rate of 25 and 35 t/ha had significantly higher soil nitrogen and phosphorus than the control. Low rate compost application did not affect sweetpotato yield.
- **A range of compost and biochar products were developed.** We developed a range of organic amendments in this project to show the other possibilities. The developed products included galip compost, garden waste compost, composted biochar and compost-biochar mixture. The compost mixed with biochar matured faster than the compost without biochar.
- **Small-scale farmers and NARI staff were trained to produce compost and biochar.** A range of training workshops were held with attendees from different provinces including East New Britain, West New Britain and New Ireland to ensure a wider community will benefit from the project.
- **Selected UNRE students were trained and mentored.** UNRE students undertaking their industry experience with NARI staff were mentored and trained in this project. The capacity building included compost production procedures, experimental design and experimental site establishment, soil and plant sample collection and data collection.
- **New biochar opportunity using biochar as charcoal.** Two unexpected outcomes of the biochar production included: (a) using the produced biochar as charcoal which was a business idea from locals and (b) having a request to undertake a biochar production workshop in Vanuatu.

Background

Intensive farming has led to decreased soil nutrient availability which in turn affects food production. Therefore, sustainable management practices are critical to replenish soil nutrients and maintain food production. Our study in cocoa-canarium and cocoa-Gliricidia plantations in PNG indicated that without adding supplements, soil in these plantations can become nutrient depleted (Bai et al. 2017). Family gardens without any fertilisation are also prone to soil nutrient depletion. Therefore, adding organic fertilisers such as compost would help to restore soil nutrients.

Adding soil supplements can be expensive and these are not affordable for the majority of small-scale farmers in PNG. Composts turn organic wastes into a nutrient-rich soil supplement. Organic waste of households and factories can be recycled through composting rather than being used as a fuel for cooking or burnt as rubbish with no or negligible benefit to the smallholder farmers.

For example, approximately 90% of canarium fruit is organic waste which can be composted and returned to soil. This project provided training to ensure recycling of organic waste in the galip factory and in the wider community.

Cited Literature

Bai, S.H., Trueman, S.J., Nevenimo, T., Hannet, G., Bapiwai, P., Poienou, M. and Wallace, H.M., 2017. Effects of shade-tree species and spacing on soil and leaf nutrient concentrations in cocoa plantations at 8 years after establishment. Agriculture, Ecosystems & Environment, 246:134-143.

Methodology/approach

Training workshops

A series of hands-on workshops on eight occasions were undertaken in East New Britain and New Ireland. The workshops were modified based on available infrastructure and the literacy of the participants. The NARI workshop was comprehensive and hence the staff were also trained to construct two different biochar kilns (single drum and double drum) in addition to compost projects. The compost manual was prepared as a leaflet and also added to the cookbook (both in English and Tok Pisin).

Field trials

Two different field trials were established.

Field trial 1: Effects of galip compost on soil nutrient availability – A trial was established at NARI in a corn field in 2018. The treatments were applied at the following rates: galip compost at 35 t/ha, 25 t/ha and 10 t/ha; wood-based biochar at 5 t/ha, galip compost at 10 t/ha mixed with low rate biochar at 5 t/ha, and control with no treatments. The corn seeds were planted immediately after treatment applications. The soil was sampled at the depth of 0-10 cm, four months following the treatment application in December 2018.

Field trial 2: Effects of galip compost on soil nutrient availability and yield of sweetpotato – A sweetpotato compost trial was also established at NARI. The galip waste material (both testa and pulp) was composted for three months before being used in this experiment. The galip composts applied at the 5 t/ha and 10 t/ha in December 2018. The leaf samples were collected when the sweetpotato was in the growing phase. The soil samples were collected in October 2019 at 0-10 cm depths, ten months following the application.

The aluminium (Al), boron (B), calcium (Ca), copper (Cu), iron (Fe), phosphorus (P), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), sulphur (S) and zinc (Zn) concentrations of soil, compost and biochar samples were measured using an ICP-OES (Optima–5300 V, Perkin-Elmer, Waltham, MA, USA) extracted with Mehlich-3 reagent. Combustion method used to measure soil total carbon (TC) and total nitrogen (TN) using a LECO (Australia Pty Ltd, Castle Hill, Australia).

Collaborative Research Grant project objectives

Objective 1: Establish a compost production expo in Kerevat, NARI and train the involved staff

Objective 2: Provide training and capacity building for composting audiences including:

- Women and youth involved in farming in villages
- Students and staff at UNRE

Objective 3: Develop a composting guideline to produce compost from farm and household wastes

Objective 4: Establish an on-farm compost trial

Project variations from the original Collaborative Research Grant application

Variation 1: One of the main variations was in Objective 4 where an establishment of on-farm compost trial was required. Originally, we were planning to apply compost to galip trees. However, in the inception workshop, NARI colleagues suggested to focus on annual crops. The majority of farmers obtain a large proportion of their income or household food from annual crops and they do not apply fertiliser to sustain their food production in the future. Compost application rates in small-scale gardens remain one of the major knowledge gaps in PNG. Therefore, the results of this project would be applicable to a wider community.

Variation 2: In addition to preparing a manual for compost production, we decided to include the concepts of composting and soil health to the cookbook prepared by Emma Kill (USC) to ensure wider community will benefit from the project. The text in the cookbook has also been translated into Tok Pisin.

Variation 3: We also included biochar production workshop using galip shells due to NARI's staff request.

Variation 4: UNRE has a composting facility and hence we did not include a composting workshop for UNRE. However, I presented the results of the compost project for both UNRE's students and staff.

Achievements against Collaborative Research Grant activities and outputs

Objective 1: ***Establish a compost production expo in Kerevat, NARI and train the involved staff***

A permanent composting site was established for future compost demonstration for NARI visitors and can also be used to produce compost on-site (Appendix 1). Two biochar kilns were also constructed, one high temperature to be used at NARI and one lower temperature suitable for farm or home use (Appendix 1).

Three senior research staff (Tio Nevenimo, Godfrey Hannet and Mathew Poienou) worked closely with the Australian team to produce both biochar and compost. Other NARI staff also participated in the workshop when we had a hands-on compost and biochar production workshop at NARI in September 2018 (Appendix 1). The NARI staff were able to successfully produce batches of biochar and compost after initial training.

Objective 2: ***Provide training and capacity building for composting audiences***

The workshop summaries include:

- 8 workshops for all ages and genders including farmers and school students were held in East New Britain and New Ireland.
- 286 farmers (family, male and female), over 10 professional staff at NARI, 3 senior researchers at NARI and Years 8 and 9 of school students at Kavieng were trained.
- Most of the workshops were undertaken in collaboration between NARI staff and Australian researchers.

The series of workshops classified into two groups

(a) turning organic waste into compost and biochar – these series of workshops aimed to

   a. train NARI staff and farmers to produce compost and biochar

   b. increase the capacity of NARI staff to design experimental trails and undertake activities related to the trial using compost and biochar

(b) merging compost production training with those undertaken for the other TADEP+ Collaborative Research Grant 'Promoting capacity building ideas for women market sellers across provinces' – Those workshops had food value adding sections leading to produce kitchen wastes. We then demonstrated that those kitchen waste could be used to produce compost. The demonstration of the full food/waste cycle was attractive for the workshop participants. The summary of aims for each project is given below.

(a) Workshop to produce compost and biochar

Workshops held in:

- Kerevat, NARI: 4 participants (1 Senior researcher and 3 professional staff)
- Kerevat NARI: 90 Participants: NARI staff and East and West New Britain
- Kerevat NARI: Ongoing face-to-face capacity building sessions were conducted over the life of the project.

The main achievements included:

- Two biochar kilns were made, one high temperature for the use at NARI and one low temperature suitable for farm or home use. Tio Nevenimo was shown how to produce and use the kilns. The NARI staff were able to successfully reproduce batches of biochar (Appendix 1).
- Workshop involved NARI staff and many local people from East and West New Britain (90 in total). The workshop was concurrent with climate change workshop and the participants from West New Britain joined the compost project.
    - A demonstration of how to make and use the single drum kiln was undertaken to show how biochar production can be performed at the homes/farms. The operation of the double drum kiln was also carried out under instruction by the NARI staff.
    - A hands-on composting workshop was also undertaken. The composting workshop involved producing two types of compost piles. One utilised material commonly found in the home/farm gardens while the second consisted of galip waste.
- The senior researchers of NARI including Tio Nevenimo, Godfrey Hannet and Mathew Poienou were shown to produce both compost and biochar. They actively participated in the experimental design, experimental establishment, data collection and manuscript writing.

(b) Merging compost production training with those undertaken for 'Promoting capacity building ideas for women market sellers across provinces'

We decided to deliver workshops as a full package for workshop attendees where they can see after value adding to their vegetable and garden food, the waste can be tuned into compost or biochar. The aim was to target larger audience and save the attendees' time.

Workshops held in:

- Rum Jungle Warangoi: 20 participants
- UNRE to Women in Agriculture: 30 participants
- Red Cross training centre Kavieng: 76 participants
- New Ireland School: school teachers, Years 5, 6 and 8, 9 and 11.
- Djoul Island workshop: 70 participants

A wide range of topics were presented across the workshops including:

- Importance of income diversification
- Importance of soil fertility and farm health – discussing tree pruning and composting - Production and use of biochar and compost
- Why organic amendments are important
- Nutritional values of galip nuts
- Galip factory products/operation and solar drying

- Baking workshop
- Health, hygiene and nutrition
- Food preservation techniques
- Composting process and discussions around household waste materials that can be used
- Careers in the galip industry
- Careers in science
- Different areas of science (environmental, social and economic)
- Sustainability, recycling, composting
- Health and hygiene (the germ game with the glitter coated ball was used for the baking workshop with the Years 5 and 6's)
- Capacity building in galip business, food safety, food processing and value adding
- Increasing knowledge in galip nutrition
- Capacity building in knowing soil leading to improve soil fertility using compost

Objective 3: ***Develop a composting guideline to produce compost from farm and household wastes***

A one-page composting guideline has been prepared (Appendix 2). Three different soil organic amendments were developed including galip shell biochar, galip waste compost, and galip waste compost and biochar mix. The nutrient concentrations of the produced organic amendments have been summarised in Table 1.

The nutrient concentrations of the galip compost indicated high nitrogen, potassium and phosphorus concentrations. Our previous studies have indicated that soils in East New Britain are nitrogen, potassium and phosphorus limited due to lack of fertilisation and intensive farming. Therefore, adding galip compost to soil would benefit the soil to replenish lost nutrients.

Table 1: Mean nutrient concentrations of galip shell biochar, galip waste compost, and mixture of galip compost and biochar (n=3)

		Galip shell biochar	Galip pulp compost*	Mixture of galip compost and biochar*
Total nitrogen	(%)	0.09	1.9	1.49
Total carbon	(%)	84.4	35.9	36.9
Aluminium	(mg/kg)	58.0	3758	4647
Boron	(mg/kg)	3.0	18.3	22
Calcium	(mg/kg)	500	11600	21800
Copper	(mg/kg)	11	24.5	39
Iron	(mg/kg)	1074	2639	4155
Potassium	(mg/kg)	130	2600	6150
Magnesium	(mg/kg)	24	900	2170
Manganese	(mg/kg)	8.0	32.5	120
Sodium	(mg/kg)	41.0	144	172
Phosphorus	(mg/kg)	0.024	0.12	0.18
Sulphur	(mg/kg)	0.003	0.34	0.27
Zinc	(mg/kg)	12.0	178	197

* those products were used in trial 1 and 2 presented in Objective d

We also included a large section in a cookbook produced by Emma Kill to cover the following subjects: healthy soil, healthy plants, when to apply compost, how to produce compost, signs of poor soil (both in English and Tok Pisin).

Objective 4: ***Establish an on-farm compost trial***

Field trial 1: Effects of galip compost on soil nutrient availability

Background: Intensive farming has led to decrease soil nutrient availability which in turn affects food production. Adding organic fertilisers such as compost would help to restore soil nutrients. However, adding soil supplements can be expensive and small-scale farmers in PNG may not afford to purchase organic amendments. Organic wastes of households and food factories can then be recycled to produce compost or biochar rather than being used as a fuel for cooking or burnt as rubbish with no or negligible benefit to the smallholder farmers. However, the application rates of organic amendment require to be optimised. This study aimed to explore the effects of compost and wood-based biochar on soil nutrient retention in a corn field.

Methods: A complete randomised block design with eight replicates was established in NARI station at Kerevat in 2018. A block consisted a planting row of 11.6 m × 0.60 m. Each block was separated from the neighbouring block using a planting row as a buffering row which received no treatments. Each block divided into eight plots (1.20 m × 0.60 m). Three corn seeds were planted at each plot and were 0.40 m apart. The two plots were separated using a plant with no treatment.

The galip compost was produced using galip pulps prior to the experiment. The treatments included compost (at the rates of 10 t/ha, 25 t/ha and 35 t/ha) and biochar mixed with compost (biochar 5 t/ha and compost 10 t/ha), biochar (5 t/ha) and control with no amendments. The nutrient concentrations of each treatment have been summarised in Table 1. The treatments were applied at the time of seed planting to the depth of 0.10 m. The plots were manually weeded at the planting time and kept weed free over the period of experiment. Soil samples (0-10 cm) were collected four months following the treatment application and used to measure the concentrations of aluminium (Al), boron (B), calcium (Ca), copper (Cu), iron (Fe), phosphorus (P), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), sulphur (S) and zinc (Zn) using an ICP-OES (Optima–5300 V, Perkin-Elmer, Waltham, MA, USA). Soil total carbon (TC) and total nitrogen (TN) were measured using combustion method. The soil samples were subject to gamma irradiation upon arrival to Australia to meet Australian Quarantine rule.

All data were examined for normality to ensure they meet the Analysis of Variance (ANOVA) assumption. One-way analysis of variance (ANOVA) was used to compare the differences in the measured soil nutrient concentrations among treatments followed by Turkey's test at $p < 0.05$ whine significant differences were observed using R software (v. 3.1.5).

Results and discussion: Soil total nitrogen and available phosphorus were significantly higher in compost treatment at 35 t/ha compared with those of other treatments (Fig. 1). The concentrations of TN were in order of com35>com25>compost+biochar>com10>biochar>control (Fig. 1). Biochar only application had higher available phosphorus concentrations than the biochar mixed with compost treatment (Fig. 1). Phosphorus concentrations varied between 7.87 mg/kg and 16.63 mg/kg with an order of com35>com25>biochar>com10>compost+biochar>control. Adding biochar to compost may have resulted in decreased compost phosphorus sorption capacity. Soil available potassium did not significantly differ among all treatments (Table 2).

No fertilisation nor organic amendment application are practiced in villages in PNG and hence the soil is both nitrogen and phosphorus limited (Bai et al. 2017; Singh et al. 2019). Soil nitrogen and phosphorus are considered limited when their concentrations are under 0.2 % in cocoa and under 26 mg/kg (Mehlich-3 ICP) in corn, respectively (Nelson et al. 2011; Hazelton et al. 2016). In this study, soil nitrogen was not limited because the land was not previously used for cropping, whereas was already phosphorus limited. The galip compost had high nitrogen and phosphorus concentrations which led to increased soil nitrogen and phosphorus concentrations in soil at the end of experiment when the corn was ready to be harvested. Therefore, high rate compost application could be recommended in nitrogen and phosphorus limited soils to replenish soil nitrogen and phosphorus.

Our study suggested that both galip compost and biochar were promising amendments to improve nutrient concentrations of soils.

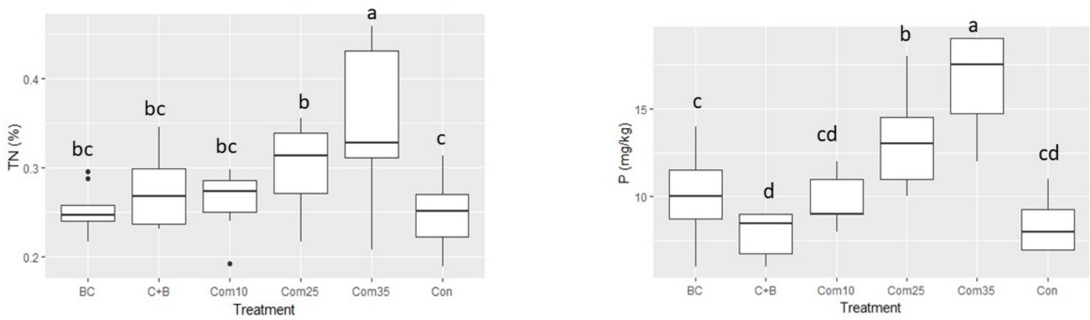

Figure 1: Soil total nitrogen (TN – left panel) and available phosphorus (P – right panel) with different amendments including biochar (BC); compost and biochar mixture (C+B); compost at 10 t/ha (Com10); compost at 25 t/ha (Com25); compost at 35 t/ha (Com35) and control (Con). Boxplots indicate the median (thick black bar), lower (0.25) and upper (0.75) quartile, minimum and maximum values (whiskers), and outliers for each dataset (i.e. close circles). Different lower-case letters in each row indicate significant differences among treatments (One-way ANOVA, P<0.05, n=8)

Table 2: Soil nutrient concentrations (mg/kg) among different soil organic amendments including biochar (BC); compost and biochar mixture (C+B); compost at 10 t/ha (Com10); compost at 25 t/ha (Com25); compost at 35 t/ha (Com35) and control, mean (standard errors) are presented, different lower-case letters in each row indicate significant differences among treatments (One-way ANOVA, P<0.05, n=8)

Soil nutrient concentrations	**BC**	**C+B**	**Com10**	**Com25**	**Com35**	**Control**
Boron	0.1±0.02a	0.3±0.1a	0.2±0.1a	0.2±0.1a	0.1±0.02a	0.1±0.08a
Copper	2.3±0.2a	2.3±0.2a	2.1±0.1a	2.1±0.05a	1.9±0.08a	1.9±0.1a
Potassium	938.2±67a	904.8±67a	840.6±47a	895.6±79a	791.2±36a	828.2±75a
Magnesium	229.0±13a	218.8±11a	232.3±14a	235.2±17a	226.6±13a	226.3±18a
Manganese	168.6±168a	168.5±7.8a	180.1±7.0a	165.6±7.8a	189.1±9.2a	175.1±11a
Sodium	24.8±3.1a	28.3±5.5a	20.8±2.3a	22.0±2.7a	24.3±2.9a	24.2±2.5a
Zinc	4.0±0.1ab	3.6±0.2b	3.8±0.3b	4.1±0.5ab	4.7±0.2a	3.7±0.3b

Cited literature

Bai, S. H. *et al.* Effects of shade-tree species and spacing on soil and leaf nutrient concentrations in cocoa plantations at 8 years after establishment. *Environ. Sci. Pollut. Res.* 246, 134–143 (2017).

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Nelson, P. N., Webb, M. J., Berthelsen, S., Curry, G., Yinil, D. & Fidelis, C. Nutritional status of cocoa in Papua New Guinea. ACIAR Technical Reports No. 76. Australian Centre for International Agricultural Research, Canberra 67 (2011).

Field trial 2: Effects of galip compost on soil nutrient availability and yield of sweetpotato

Background: Annual crops including sweetpotato are important sources of income for small-scale farmers in Papua New Guinea. It is highly important that crop yields are maintained to sustain food security for small-scale farmers. Therefore, adding soil organic amendments including compost are recommended to replenish soil nutrients leading to sustain crop yield. However, farmers may not be able to produce compost in large scale due to space and labour needed to produce large volume of organic amendments. Hence, they might be able to produce compost in small volumes and add organic amendments in low rates annually. This study aimed to explore the effects of low rate galip compost on sweetpotato yield.

Methods: The galip compost was produced on site prior to the experiment. The galip pulp were piled and covered by a plastic bag for three months. The pile was turned every fortnight and kept moist until the compost reached the maturity. Sweetpotato compost trial was then established at NARI, Kerevat in December 2018 using a complete randomised block design with eight replicates. The treatments included compost (at the rates of 10 t/ha, 25 t/ha and 35 t/ha) and biochar mixed with compost (biochar 5 t/ha and compost 10 t/ha), biochar (5 t/ha) and control with no amendments. The nutrient concentrations of galip compost has been summarised in Table 1. The treatments were applied at the time of seed planting to the depth of 0.10 m. The plots were manually weeded at the planting time and kept weed free over the period of experiment. Leaf samples were collected when the sweetpotato was in middle of growth period in January 2019. Three fully expanded mature leaves was selected at each plant for this purpose. The leaf samples were dried at 60 °C and ground to a fine power. The three leaves per plant were pooled to constitute one sample per plant. Soil samples (0-10 cm) were collected following the sweetpotato harvest where the treatments had been originally applied. The nutrient concentrations of both soil and leaf samples were analysed. The measured nutrients included aluminium (Al), boron (B), calcium (Ca), copper (Cu), iron (Fe), phosphorus (P), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), sulphur (S) and zinc (Zn) using an ICP-OES (Optima–5300 V, Perkin-Elmer, Waltham, MA, USA). Soil total carbon (TC) and total nitrogen (TN) were measured using combustion method. The sweetpotato tubers were also harvested in April/May 2019 and their fresh biomass was recorded after all particles were removed from the surface of tubers. The leaf and soil samples were subject to gamma irradiation upon arrival to Australia to meet Australian Quarantine rule.

One-way analysis of variance (ANOVA) was used to compare the differences in the measured sweetpotato yield, soil nutrient concentrations and foliar nutrient concentrations among treatments using IBM SPSS Statistics v26.

Results and discussion: Results of the sweetpotato trial indicated no significant differences in sweetpotato yield (Fig. 2). We also did not find any significant differences in soil and foliar nutrient concentrations (Table 3). Nitrogen and phosphorus concentrations were on average 1.1 % and 6.8 %, respectively (Table 3).

Lack of significant differences in nutrient concentrations of soil explained lack of differences observed in sweetpotato. This experiment also supported our findings in corn experiment where compost applications rate of 10 t/ha did not affect soil nutrient concentrations comparted with the control (Table 2). Therefore, it is important that galip compost is applied in rates over 20 t/ha to increase soil nutriment concentrations including nitrogen and phosphorus within the first planting season. We hypothesised had that applying organic amendment over years would improve soil nutrient availability leading to increased crop yield.

Figure 2: Sweetpotato harvest in the compost trial at NARI station (left) and mean (standard errors) among control, compost at 5 t/ha (Com5) and compost at 10 t/ha (Com10) (right). The weights are per plant. No significant differences were observed in sweetpotato fresh weight among treatments (One-way ANOVA, P>0.05, n=8)

Table 3: Soil and foliar nutrient concentrations among different soil organic amendments including compost at 5 t/ha (Com5); compost at 10 t/ha (Com10); and control, mean (standard errors) are presented, no significant differences among treatments were observed (One-way ANOVA, n=8)

Soil nutrient concentrations		**Control**		**Com5**		**Com10**	
Total carbon	Wt %	2.4	±0.15	2.4	±0.13	2.5	±0.18
Total nitrogen	Wt %	1.1	±0.01	1.1	±0.02	1.1	±0.03
Aluminium	mg/kg	1145.1	±40.81	1133.6	±41.11	1117.0	±38.24
Boron	mg/kg	0.6	±0.11	0.6	±0.12	0.6	±0.10
Calcium	Wt %	1501.8	±43.68	1532.3	±63.72	1547.5	±57.07
Copper	mg/kg	1.1	±0.05	1.1	±0.07	1.2	±0.07
Iron	mg/kg	100.7	±5.08	103.1	±4.29	100.6	±5.56
Potassium	Wt %	608.8	±84.11	682.1	±64.85	723.8	±54.01
Magnesium	Wt %	207.2	±7.39	217.3	±10.38	232.3	±11.63
Manganese	mg/kg	13.5	±1.35	13.4	±1.29	18.0	±2.83
Sodium	mg/kg	11.5	±1.26	9.0	±1.27	11.0	±1.41
Phosphorus	Wt %	6.8	±1.05	6.7	±0.71	6.9	±0.65
Sulphur	Wt %	19.2	±2.00	29.6	±8.39	21.3	±2.67
Zinc	mg/kg	1.5	±0.15	1.6	±0.15	1.5	±0.12
Foliar nutrient concentrations		**Control**		**Com5**		**Com10**	
Total carbon	Wt %	41.8	±0.17	41.9	±0.14	41.9	±0.17
Total nitrogen	Wt %	5.9	±0.16	5.7	±0.12	5.9	±0.11
Aluminium	mg/kg	89.6	±23.11	74.1	±13.87	65.8	±8.58
Boron	mg/kg	25.6	±2.85	24.6	±2.89	26.1	±2.67
Calcium	Wt %	0.6	±0.05	0.5	±0.04	0.6	±0.05
Copper	mg/kg	17.2	±0.92	15.6	±0.92	17.0	±0.68
Iron	mg/kg	119.7	±5.34	123.1	±6.23	118.0	±6.60
Potassium	Wt %	4.9	±0.14	4.5	±0.22	4.7	±0.14
Magnesium	Wt %	0.3	±0.005	0.3	±0.01	0.3	±0.01
Manganese	mg/kg	41.7	±1.23	39.5	±1.46	43.5	±3.12
Sodium	mg/kg	104.0	±12.91	120.2	±16.30	109.2	±10.50
Phosphorus	Wt %	0.5	±0.02	0.5	±0.02	0.5	±0.02
Sulphur	Wt %	0.3	±0.01	0.3	±0.02	0.3	±0.01
Zinc	mg/kg	33.2	±1.61	33.7	±1.17	33.7	±0.95

Impacts against TADEP+ program objectives

Private sector-led development

Three private sector processors are eager to value add to the galip waste in a small-scale.

Dorothy Luana is currently applying galip testa directly in the farm and is also keen to explore using testa as livestock feed and compost in the future.

Equanut intends to produce charcoal in the future.

The third private sector processor, Votausi McKenzie from Lapita Café has invited us to carry out a biochar workshop in Vanuatu. This private processor intends to produce charcoal to be sold for cooking and biochar to be sold as soil amendments.

Agricultural productivity, quality and value

Volcanic soils are naturally poor in phosphorus and intensive agricultural productions without replenishing soil nutrients can lead to decreased food production in the future. This project provided scientific information indicating the importance of adding organic amendments to soil to replenish soil nutrient. It also indicated that the applications rates needed to be optimised to ensure soil nutrient availability will be impacted.

Access to market and value chains

Developing soil organic amendments including compost, biochar, biochar-based fertiliser and composted biochar can be explored. Market access for those products in rural areas might be challenging. The farmers are not used to purchasing fertiliser/organic amendments in general and change in practices need to be accompanied by increased awareness and education. However, talking with some farmers highlighted the fact that using charcoal for cooking was promising as additional income whereas composting was identified as a small operation in farms.

Gender equality and women's empowerment

We did not exclude male participants from our workshops. However, most participants in all workshops were usually female. We also invited women participants to take part in a challenge in two of the hands-on workshops to ensure they enjoyed the experience while they are learning.

Individual and institutional capacity building

The NARI staff are now capable to carry out similar workshops including both compost and biochar production. Mathew Poienou took a leading role to supervise UNRE students to increase their knowledge in this area of research.

Figures 3 and 4: Mathew Poienou (NARI), Michael Farrar (USC) and Dr Shahla Hosseini Bai (USC) demonstrating how to make compost to workshop attendees at NARI, Kerevat, East New Britain (left) and Mathew Poienou (NARI) supervising UNRE students to share knowledge to develop organic amendment (right).

Collaboration

Examples of collaborative approaches, methodologies

All activities were delivered collaboratively among project teams involved within the current project including material prepared for workshops, workshop deliveries, experimental designs, data collection and manuscript writing. The project team members had regular meetings and communications to undertake the activities.

Figures 5 and 6: Collaborative workshop delivery with soil cocoa team and NARI team, Godfrey Hannet, Shahla Hosseini-Bai, Chris Fidelis and Kanika Singh presenting at UNRE and Kerevat NARI.

Figure 7: Family Farm Teams trainer, Robert Taula, helping to deliver workshop in Djoul Island, a remote island in New Ireland province.

The contribution of each team for project objectives as follows

- Establish a compost production expo in Kerevat, NARI and train the involved staff.

  FST/2014/099: Enhancing private sector-led development of the canarium industry in PNG and SMCN/2014/048: Optimising soil management and health in Papua New Guinea integrated cocoa farming systems, contributed in

  - Workshop development and delivery of all compost and biochar production

- Preparation of manuals and soil health chapter

- Capacity building:

  FST/2014/099: Enhancing private sector-led development of the canarium industry in PNG,

  ASEM-2014-095: Improving opportunities for economic development for women smallholders in rural PNG, SMCN/2014/048: Optimising soil management and health in Papua New Guinea integrated cocoa farming systems; and CRG: Promoting capacity building ideas for women market sellers across provinces, contributed in

  - Workshop development and delivery of all compost and biochar production – for example, all workshops undertaken in New Ireland hold in collaboration with ASEM-2014-095 project.
  - Preparation of manuals and soil health chapter

- Develop a composting guideline to produce compost from farm and household wastes, and
- Establish an on-farm compost trial

  FST/2014/099: Enhancing private sector-led development of the canarium industry in PNG and SMCN/2014/048: Optimising soil management and health in Papua New Guinea integrated cocoa farming systems, contributed in

  - Workshop development and delivery of all compost and biochar production
  - Preparation of manuals and soil health chapter
  - Capacity building for research skills at NARI
  - Design and establishment of two field trials

What worked, what didn't work, areas for improvement

What worked:

- Merging workshops with food value adding workshops
- Hands-on and interactive workshop delivery
- Adding biochar workshop to compost workshop
- Validating the compost effects on soil nutrient concentrations using field trials
- Interdisciplinary approach across three projects to deliver the activities
- Involving NARI researchers and small-scale farmers in workshops
- Having both large scale and small-scale workshop sessions

What didn't work:

- Cocoa team played an important role in developing compost protocol from galip pulps. However, we did not have any cocoa compost to compare with galip compost.

- We were not able to examine a wide range of composts within diverse planting systems especially those important for family food in villages.
- Our limited follow ups with farmers indicated that they have started applying raw kitchen waste (e.g. galip testa) to the home gardens.
- New Ireland weather restricted our activities in New Ireland.
- Delays in fund transfer when project leader changed the institution.

Areas for improvement:

- The composting trials needs to be expanded. One of major questions in workshops was related to optimal rate of compost produce from household waste. We were unable to answer this question.
- The gender participation in workshops needs to be more accurately recorded in the future.
- Barriers to produce compost in home gardens require to be identified
- Long term data collection needs to be considered, all data were collected within one planting season

Key learnings

The key learning included:

- The application rates of compost produced locally require to be optimised which was not possible to be undertaken for wide range of home garden crops within this project. The main findings included:
    - High rate compost application (25 and 35 t/ha) led to increase soil nutrient concentrations.
    - Low rate compost application did not increase sweetpotato yield. However, it was hypothesised that the repeat application over years would improve soil nutrient and crop yields and it is more feasible for farmers to apply low rate organic amendments in their farms.
- Producing compost can be time-consuming which was identified as one of the barriers to the use of this technology in farms.
- Delivering compost workshops with food related workshops led by Emma Kill (USC) made the concept more tangible for the audience. There was always a ‘wow moment’ when participants realised the importance of food waste in their homes.
- Hands-on workshops were highly appreciated from the participants based on the verbal feedback.

Conclusions and any recommendations

The key conclusions include:

- Well replicated scientific trials (n=8) indicated the importance of optimising application rates. The galip compost at the rate of 25 and 35 t/ha led to increase soil nutrient concentrations compared with control soil. Low rate compost application did not affect sweetpotato yield. However, the major aim was to add low rate organic amendments over a few years. The low rate application of compost might be more feasible in the small gardens. Hence, we will repeat the practice in the future.
- Galip compost was ready to be used after three months. It was also interesting to discover that the compost mixed with biochar matured faster than those with no biochar, most likely due to increased water holding capacity of the compost.
- A wide range of compost and biochar products including galip compost, composted biochar and compost-biochar mixture was developed in this project.
- 286 farmers (family, male and female), over 10 professional staff at NARI, 3 senior researchers at NARI and Year 8 and 9 of school students at Kavieng were trained to produce organic amendments across eight workshops.
- Two unexpected outcomes of the biochar production included: (a) using the produced biochar as charcoal which was a business idea and (b) having a request to undertake a biochar production workshop in Vanuatu.

The main recommendations for future work include:

- Develop a guideline for nutrient sensitive home gardens by exploring the nutritional value of the crops and their effects to every day nutrient intake of families when organic amendments are applied.
- Explore the gender roles in the production of compost and biochar to ensure equity across gender and age
- Understand enablers and barriers of using organic amendments in small-scale operations.
- Optimise the application rates of organic amendment to a wide range of household crops. It is highly likely that the application rate is crop and site dependent.
- Undertake a study to investigate the feasibility of compost, biochar and organic fertiliser production as a business in Pacific – the demand for clean organic fertilisers are growing rapidly worldwide, while this can bring an opportunity, it can also present a challenge if not managed properly.

Appendices

Appendix 1: Some images from the project activities and workshops

Figures 8 and 9: A two-cell cubical compost pit (left) and compost pit hole (right) were constructed at NARI station, Kerevat.

Figure 10: A large-scale composting facility located in New Ireland, Nusa Resort, visited in Jan 2019.

Figure 11: Alfred (NARI staff) using grinder to construct a double drum kiln and a single drum kiln.

Figures 12 and 13: Making biochar from galip shells with NARI staff using both single and double drum kilns, Kerevat, East New Britain.

Figure 14: Mixing biochar with compost material to produce composted biochar. Adding biochar led to a faster compost maturing compared with that of no biochar in the compost mix.

Figures 15 and 16: UNRE students participated in the establishment of sweetpotato and compost trial under supervision of the NARI staff (left). Discussing the importance of the soil fertility for the attendees of the NARI workshop (right).

Figure 17: The lecture room at WIA delivering compost workshop. The workshop was very interactive with local scientists and female farmers participating in the discussion panel.

Figure 18: A farm visit at Dorothy's place, Rum Jungle Warangoi to discuss farm health, composting, and income diversification

Figures 19 and 20: Mixing compost and biochar treatments to soil just before corn planting in August 2018 (left) and corn growing well (right), data have been presented in trial 1.

Figure 21: Mathew and NARI team helping to collect subsample soil for compost project (effects of galip compost on soil nutrient concentration in a sweet potato farm – trial 2)

Appendix 2: A simple leaflet to make compost prepared

How to make your compost?

1 Pick a shady spot
2 Dig the compost pits down

Or build a cubical framework with two or three cells for old and fresh material

3 Get kitchen skins from your kitchen, and other natural material (garden clipping)

4 Layer up the fruit skins and garden clippings

5 Keep layering unit pit is full or just over

6 Wet down compost pit

7 Turn compost every week and add water again if it is dry

8 Cover the compost pile

9 Compost is ready to use usually after 3 months – black or brown colour and has a clean dirt smell