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Agronomic Value of Composted Organic Waste Application on Porous Soils of Northern Guam

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ABSTRACT

As an alternative to the application of commercial synthetic fertilizers on land, composted organic wastes can be applied as organic fertilizer for crop production. This is a more viable waste-management system based on 'resource recovery' strategy. We compared applications of 0, 30, 60 and 90 tons (dry weight) per acre of composted organic waste with application of commercial inorganic fertilizers containing equivalent amounts of nitrogen over three growing seasons in northern Guam soils. In season 1 (dry season), the yield from plots receiving compost (compost plots) was not significantly higher (p = 0.05) than the plots receiving synthetic fertilizer (fertilizer plots). In season 2, when no compost was applied (for residual effect) but inorganic fertilizer application was continued, the 60- and 90-ton per acre compost applied plots showed a significantly higher yield than control (0-ton compost) plots. However, fertilizer plots performed better than compost plots overall. During season 3 (rainy season), on the other hand, compost was reapplied, as was the inorganic fertilizer. The 90-ton compost plots showed higher yields than equivalent fertilizer plots. Soil organic matter contents of all compost plots were also statistically higher than those of fertilizer plots throughout the study.

Keyword: **Calcareous soils, maize, compost, soil organic matter, soils of Guam.**

INTRODUCTION

The presence of agronomic development of Guam and its neighboring islands may be constrained by the limited availability of composted organic material to farmers. Farmers generally rely on commercial synthetic fertilizers for crop production, but the resulting long-term benefits to soil fertility are questionable. Guam's increasing population and its tourism industry, together with limited subsistence farmlands, can put pressure on food availability and its restricted Integrated Solid Waste Management Program (landfill).

One of the major concerns of agricultural production in Guam and other tropical islands of Micronesia is the low soil organic matter content, specifically of

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the calcareous farms on northern Guam (Golabi *et al*. 2004). According to Jackson *et al*. (2003), application of composted organic waste increases soil microbial biomass, total soil carbon and nitrogen, reduces soil bulk density, and decreases the potential for groundwater pollution that would otherwise result from nitrate leaching below the root zone. The bulk of the land on Guam is unsuitable for subsistence farming because of poor chemical and physical characteristics of the soils. On the other hand, up to 77% of wastes generated from Guam's households are organic and can be used as composting material (Golabi *et al*. 2014). The application and continued addition of composted organic matter can create a soft, tillable, and healthy soil for plant growth as well as reduce the amount of biodegradable material going into the landfill. The addition of composted organic waste to the soil significantly changed the soil-quality by improving its bulk density, soil organic-matter content, as well as its nutrient content (Karolle 1991).

Golabi *et al.* (2007) has reported that composted organic-waste application in a southern Guam soil resulted in higher crop yield (of maize) and improved soil fertility and health. It is worth mentioning that the southern Guam soil used in that project were eroded Akina soil series which are formed from volcanic rock having a pH range of 5.2 to 6.4, an indication of an acidic soil covering southern Guam. On the other hand, the pH range of the northern Guam soils used in the present study have a pH range of 7.1 to 7.9 indicating that the soils of northern Guam are much more alkaline in nature due to the calcareous properties of their parent material. The present study therefore evaluates the agronomic value of organic waste application and its effect on crop productivity and agricultural sustainability on calcareous soils of northern Guam.

MATERIALS AND METHODS

Experimental Site

Our study was conducted from August 2013 to December 2016 at the University of Guam's Yigo Research Station in northern Guam. Guam has a tropical climate with an annual rainfall of 2540 mm and a distinct dry season between January and June, during which the rainfall averages approximately 800 mm (Lander 1994). The mean annual temperature is 26°C, and the monthly temperature range varies approximately ±2°C from the mean (Karolle 1991).

The soil type underlying the study site and also the dominant soil in northern Guam is of 'Guam soil series'(clayey, gibbsitic, non-acid, isohypothermic lithic Ustorthents) from Entisols order, formed in sediment over porous coralline limestone (Young 1988). Entisols exhibit thin or no soil profile or horizon development and are often found in places where deposition is faster than the rate of soil development (USDA-SCS 1988). The bedrocks underneath these soils are highly porous, so soil water can easily percolate into the groundwater aquifer that supplies 80% of the island's drinking-water supply (WERI 2017). The soil's permeability is moderately rapid, and water availability is also very low. Effective rooting depth ranges from 5 to 41 cm (USDA-SCS 1988).

Plot Description and Design

Each of the 28 study plots had an area of 42.7 m^2 (7 m by 6.1 m) with eight 6.1 m rows of maize plants; spacing between rows was 0.76 m. Seeds were sown directly, 0.3 m apart. A randomized complete block design with four replications (blocks) was used to control for variation in soil fertility or structure (Washington State University 2018). Plots within blocks were 1.5 m apart, whereas replicated blocks were 3 m apart.

Composted organic waste was applied to half the plots. Treatments levels were 0 (control), 30, 60, and 90 tons (dry weight) per acre. The other half of the 28 plots received levels of synthetic fertilizer (16-16-16) chosen to provide equivalent amounts of nitrogen (N) as the compost treatments plots (Table 1).

TABLE 1

Rates of application of compost and inorganic fertilizer to experimental plots

Compost (tons/acre, dry weight)	**Compost** (kg/plot, 40% moisture)	**Inorganic fertilizer** [(16-16-16), kg/plot]
0	0	0
30	287.40	6.35
60	574.8	12.70
90	862.19	19.30

Composting and Compost Application

The raw materials used in compost making consisted of, leftover restaurant food and paper products, woodchips from Anderson Air Force Base in Guam, coconut leaves from the rhinoceros-beetle eradication project, and hog and chicken manures from local farms. In order to obtain enough compost for the study, a large-scale mechanical composting was used prior to the land application of the organic material. For this purpose, a large active aerated windrow was mixed regularly by a mechanical compost turner pulled behind a tractor. The entire amount of compost designated for each plot was applied once, just a week before planting and it was spread as a uniform layer over the entire plot.

Inorganic Fertilizer Application

The inorganic fertilizer was applied in two halves (application event); the first application event was just two weeks after planting and the second was six weeks after planting. In both cases, it was applied as a narrow band to the surface of the soil, adjacent to the row of maize seedlings.

Irrigation

Water drip lines (20 emitters per row) were used with automatic timers to irrigate the crops for two hours, twice daily. As the maize ears neared maturity, irrigation time was reduced to one hour once a day. Adjustments were made during lengthy rains, storms, and dry or wet seasons to minimize erosion and to control soil moisture. Because instrumentation was not available, irrigation was based on perceived plant requirements.

Soil and Compost Testing and Analyses

Total Carbon and Nitrogen Content

The percentages of carbon (C) and nitrogen (N) in the soil and in the compost were determined with a FlashEA 1112 instrument made by Thermo Electronic Corporation. The percentages of C and N obtained were used to determine the C-to-N ratio (C: N). A proper C: N ratio is important for successful aerobic composting and for production of high-quality compost. Both compost and soil used in this project were analyzed for C: N before and after planting.

Phosphorus

Phosphorus (P) is an essential nutrient (required for plant DNA, RNA, and energy transfer for growth and development) and is often the limiting nutrient after N (Conley *et al.* 2009). Although excess P is not considered toxic to humans, a high concentration of P in fresh water can lead to nutrient pollution or eutrophication due to the rapid growth of algae. Runoff of excess P from farmlands can reach nearby streams, rivers, lakes, and surrounding beaches and adversely affect the local tourism industry, a major contributor to Guam's economy.

Phosphorus used in farming is in the form of phosphate. Most phosphatic fertilizers are made from highly pure monocalcium ($CaHPO_4$) and/or dicalcium ($Ca(H_2PO_4)_2$) orthophosphate (Van Wazer 2014). Although P is found in many types of soils, its availability is limited by phosphate aging (formation of calcium phosphate, called phosphate fixation) when the soil pH is above 7.5 (Richardson *et al*. 2011), as in the calcareous soils of northern Guam. We therefore tested the soil from each plot and the compost used for P, using the Olsen-P determination method by means of a spectrophotometer.

Exchangeable Potassium, Magnesium, and Calcium:

Essential macronutrients such as potassium (K) and calcium (Ca) as well as micronutrients such as magnesium (Mg) from the prepared compost and soil samples were measured by atomic absorption spectrometry by means of direct aspiration into an air-acetylene flame (Fishman and Downs 1966). Samples from the composted organic waste were taken before application to the study plots, and soil samples were taken before planting.

Soil pH Analysis

Soil pH is the measure of acidity and alkalinity and is important in many chemical processes such as plant nutrient availability and overall soil health. As the soils of northern Guam are calcareous and also because of the effects of crop residues on the soil's chemistry, pH testing was performed to determine overall soil quality (Butterly *et al.* 2013) during the study period.

We determined soil pH by using an Oakton glass eletrode pH meter, adjusted to 1:2 ratio of soil and water considering the texture of both soil and the compost (Sparks *et al*. 1996).

Soil Organic Matter

Soil organic matter (SOM) is formed from decomposed plants or animals in various stages of breakdown, including the stable component known as humus (Cornell University Fact Sheet 2018). SOM serves as an effective reservoir of nutrients for crops, and improves soil aggregation, increases nutrient exchange capacity, retains moisture, reduces compaction and surface crusting, and also increases water infiltration rate into the soil matrix (SSSA 2008).

The Walkley-Black acid digestion method and a nitrogen carbon analyser were used to test for SOM, and C and N content of both the soil and the compost used for this project. The Walkley-Black method is known to be more accurate on soils with less than 2% organic matter (Agvise Laboratories 2018).

Bulk Density

The critical value of bulk density for restricting root growth varies with soil type, but in general, bulk densities greater than 1.6 g/cm^3 tend to restrict root growth (Hunt and Gilkes 1992; McKenzie *et al*. 2004). In the present study, the soil plots were tilled before application of either compost or fertilizer. Also, most soil plots contained a high number of sodium carbonate rocks which increased the bulk density of the samples.

Electrical Conductivity

Electrical conductivity (EC) is a measurement of soil salinity, which is often associated with irrigated farmlands or with shallow water tables in arid-zone regions (Corwin and Lesch 2005). Although plants absorb nutrients in the form of soluble salts, excessive salinity can adversely affect plant growth (Shrivastava and Kumar 2015). As the soil of northern Guam is highly porous and regularly receives high amounts of rain, any increase in salinity can be attributed to excess application of composted organic wastes.

Statistical Analysis

A non-parametric Friedman test was used to determine significant differences in crop yield ($p < 0.05$) with the randomized complete block design in mind. Minitab version 17 Software was used for the analyses.

RESULTS

Soil pH Levels

Soil pH of the study area in Northern Guam is inherently high and remains in the alkaline level under natural conditions. However, cultivation of agronomic crops with the compost applied treatments tends to stabilize the pH towards neutral conditions. As shown in Table 2, pH determination throughout the study period indicated that the pH level remained close to 7 in the control plots during the period of the experiment but that of the compost plots were stabilized at around 6.8, indicating that compost had the ability to maintain a balanced pH throughout the study period. On the other hand, fertilizer application tended to increase the pH level (although not significantly) or remain the same as the control. As reported by Golabi *et al.* (2007), application of compost as a soil amendment increases the pH of acidic soils and decreases that of alkaline soils thus reaching a more balanced soil pH in each region. Our study results agree with this conclusion.

TABLE 2
Average pH values of soils from each study plot as they were determined prior to the treatments and just before each planting seasons during the experimental period

Treatment	Before treatment or planting	Planting **season 1**	Planting **season 2**	Planting **season 3**
Control	7.34	7.02	7.07	6.98
Compost 30	7.20	6.92	6.93	6.90
Compost 60	7.17	6.88	6.91	6.83
Compost 90	7.06	6.76	6.74	6.67
Fertilizer 30	7.51	7.06	7.01	6.92
Fertilizer 60	7.08	7.05	7.03	6.98
Fertilizer 90	7.01	6.93	6.98	6.91

Soil Nutrient Analysis

Tables 3 through table 5, list the results of the nutrient analyses. Note that compost was not applied during the second planting season. This procedure was conducted to observe the carry-over effect of compost application from the first planting season. To this effect, Table 4 shows that there was the carry-over effect on nutrient content from the first season's compost application. Compost was again applied in season 3, as shown in Table 5. Tables 3 through 5 make it clear that both compost and inorganic fertilizer increased the percentages of soil carbon and soil nitrogen. In addition, C:N decreased especially at the higher application rates. Content of other nutrients (phosphorus, potassium, calcium, and magnesium) also increased as the compost application rates were increased. In season 2, the high nutrient content persisted in the compost plots, even though compost was not applied. This clearly shows that, residual benefits of compost application on treatment plots last longer than those of synthetic fertilizers.

TABLE 3
Average nutrient content of soil during first week of planting in season 1 (August 2013 to February 2014, during which both compost as well as fertilizers were reapplied)

Treatment	%C	%N	C:N	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Control	8.56	0.21	42:1	6.1	46.5	9,732.8	78.1
Compost 30	6.60	0.26	26:1	7.0	84.9	9,201.0	122.1
Compost 60	11.59	0.44	26:1	18.6	104.1	11,887.3	224.5
Compost 90	8.02	0.33	25:1	13.6	82.7	10,920.5	207.3
Fertilizer 30	10.18	0.26	39:1	8.2	71.0	11,340.3	76.0
Fertilizer 60	10.16	0.23	45:1	12.8	56.3	9,527.3	74.0
Fertilizer 90	11.46	0.28	42:1	17.3	85.4	11,344.5	111.3

TABLE 4
Average nutrient content of soil during first week of planting in season 2 (August 2014 to February 2015, during which compost was not reapplied)

Treatment	%C	%N	C:N	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Control	8.76	0.24	37:1	9.7	53.0	10,037.0	90.8
Compost 30	8.70	0.38	23:1	22.2	99.0	9,699.5	195.3
Compost 60	11.91	0.51	23:1	35.9	229.3	12,125.5	324.8
Compost 90	11.50	0.50	23:1	43.1	313.5	11,266.3	405.3
Fertilizer 30	10.18	0.25	41:1	10.9	55.3	9,567.8	122.8
Fertilizer 60	10.01	0.28	36:1	15.3	69.0	8,349.0	117.5
Fertilizer 90	11.31	0.29	39:1	26.6	84.5	10,778.5	147/8

TABLE 5
Average nutrient content of soil during first week of planting in season 3 (September 2016 to December 2016, during which both compost as well as fertilizers were reapplied)

Treatment	% C	% N	C:N	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Control	9.6	0.33	29:1	10.9	48.5	10,203.8	82.3
Compost 30	9.2	0.44	21:1	19.9	76.0	10,967.3	133.5
Compost 60	11.8	0.53	22:1	32.6	88.0	13,416.0	194.0
Compost 90	10.7	0.53	20:1	19.9	83.0	12,882.3	213/0
Fertilizer 30	11.4	0.38	30:1	16.2	104.3	10,319.5	85.3
Fertilizer 60	12.1	0.39	31:1	20.7	131.3	10,304.5	83.8
Fertilizer 90	12.1	0.40	30:1	33.9	236.3	9,317.5	87.3

Soil Organic Matter

As shown in Figures 1 through Figure 3, the organic matter content of the soil increased gradually in all compost applied plots throughout the experimental period. The organic matter content of the soil continued to increase (Figure 2) in the second season, even though additional compost was not applied. Except during the first season of the experiment, the organic matter content of the soil gradually increased with increasing application rates of the compost (Figures 1–3).

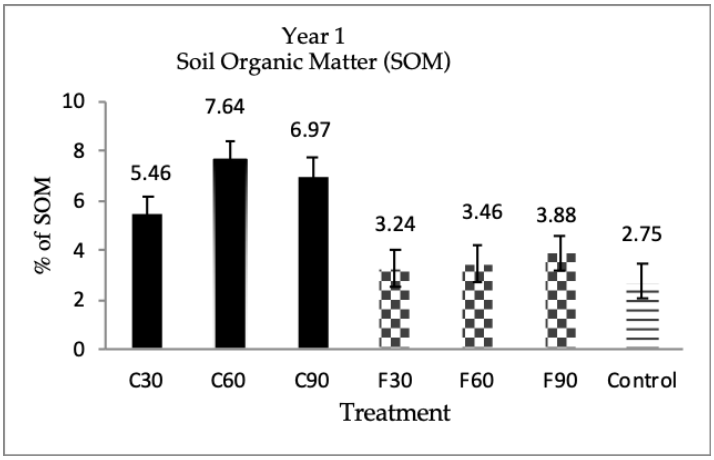

Figure 1. Average soil organic matter (SOM) content during planting season 1. C30, C60, and C90 represent plots receiving 30, 60, and 90 tons (dry weight) of compost per acre. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Control plots received no compost or fertiliser.

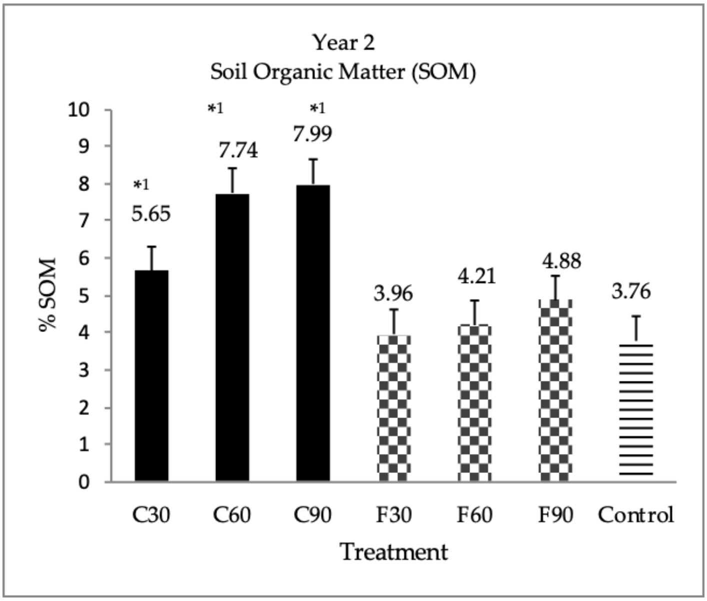

Figure 2. Average soil organic matter (SOM) during planting season 2. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Plots designated for compost (C) received no treatment. Control plots received no compost or fertilizer. Effects on SOM of compost application during season 1 carried over into season 2.

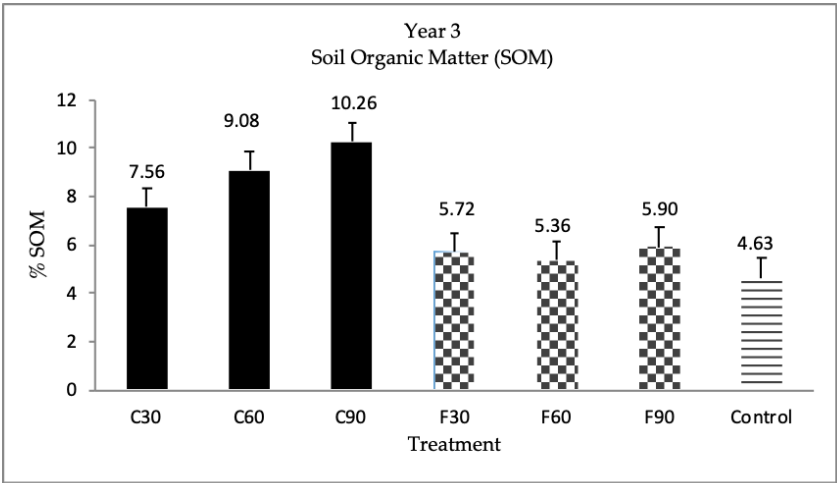

Figure 3. Average soil organic matter (SOM) during planting season 3. C30, C60, and C90 represent plots receiving 30, 60, and 90 tons (dry weight) of compost per acre. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Control plots received no compost or fertilizer.

Bulk Density

The bulk density of the soils under study remained identical to the control (steadily high) on the fertilizer applied plots. On the other hand, as shown in Figure 4, the average bulk density of the soil continued to decrease as the amount of compost applied to the study plots increased. This finding agreed with the conclusion made by other researchers (Jackson *et al.*, 2003) regarding the beneficial effect of compost on the physical properties of the soil.

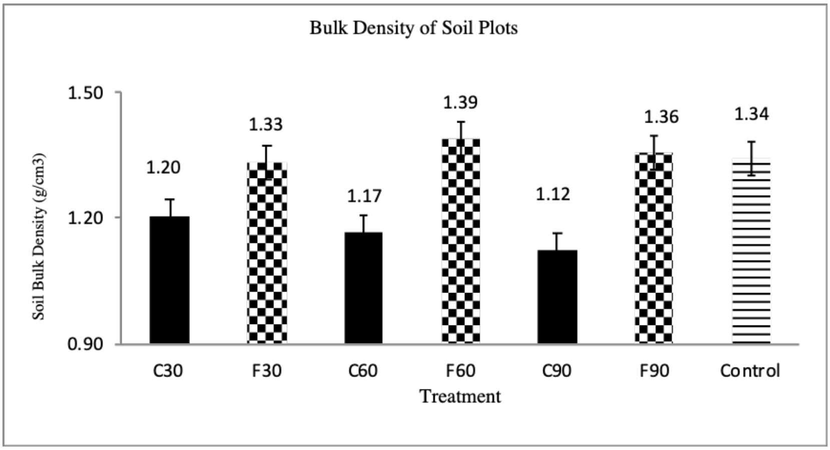

Figure 4. Showing Bulk density (g/cm3) of soils for all plots after three seasons of planting and harvesting. C30, C60, and C90 represent plots receiving 30, 60, and 90 tons (dry weight) of compost per acre. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Control plots received no compost or fertilizer.

Electrical Conductivity

Although application of compost can improve soil fertility, some of its components may contain salt, and research results (Reddy and Crohn 2012) have indicated that compost of high salt content can negatively affect plant growth. In our study, however, the effects of composted organic wastes on soil salinity were minimal (Table 6). Soils were tested for salinity before and after harvest in season 3, and results showed (Table 6) that the electrical conductivity of the compost applied plots had decreased following the harvest.

Crop Yield

As shown in Figures 5 through 7, yield varied during the experimental period. In season one, the yield was higher on the compost applied plots than on the corresponding fertiliser plots, regardless of application rates (Figure 5). In season two, when fertilizer applied plots continued receiveing same rate of fertiliser application as they received in season one, the yield was considerably higher as compared with the corresponding compost applied plots.

TABLE 6
Electrical conductivity (a measure of soil salinity) on each study plots were measured just before planting and immediately after the harvest during the 3rd planting season

Treatment	Average dS/m before planting	Suitability for agriculture	Average dS/m after harvest	Suitability for agriculture
Control	0.20	Excellent	0.14	Excellent
Compost 30	0.26	Good	0.20	Excellent
Compost 60	0.24	Good	0.20	Excellent
Compost 90	0.27	Good	0.21	Excellent
Fertilizer 30	0.22	Excellent	0.16	Excellent
Fertilizer 60	0.24	Excellent	0.16	Excellent
Fertilizer 90	0.24	Excellent	0.17	Excellent

Although, yields on compost plots were lower than those of the corresponding fertiliser plots, they continued to be higher than the control plots. In season three hoewvver, the 90 tons per acre of compost applied plots showed considerably higher yield than those of the cooresponding fertilizer applied plots with equivalent application rate.

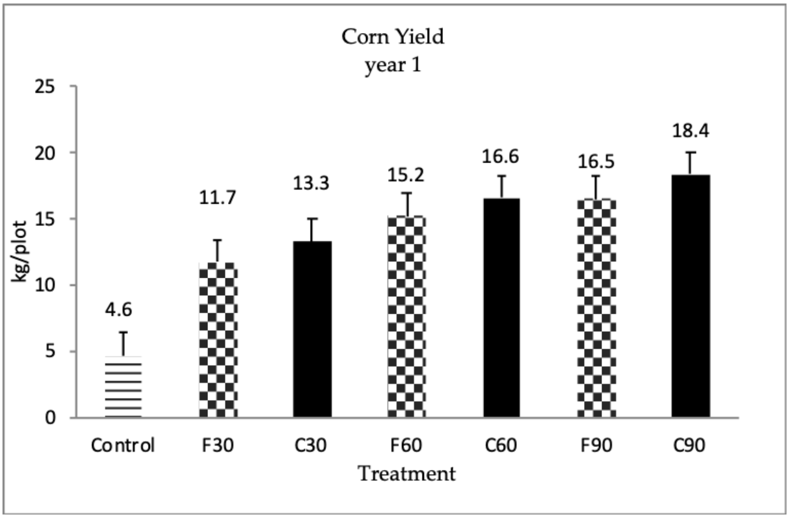

Figure 5. Yield of maize from planting season 1. C30, C60, and C90 represent plots receiving 30, 60, and 90 tons (dry weight) of compost per acre. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Control plots received no compost or fertilizer.

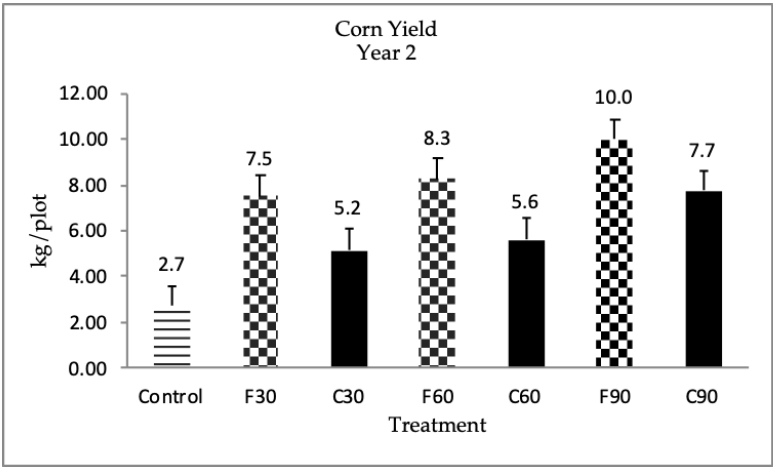

Figure 6. Yield from planting season 2 during which plots designated for compost received no treatment. C30, C60, and C90 represent plots receiving 30, 60, and 90 tons (dry weight) of compost per acre. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Control plots received no compost or fertilizer.

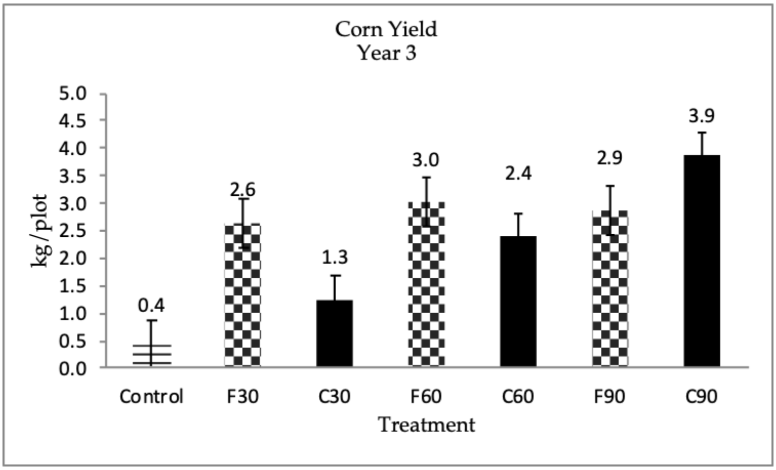

Figure 7. Yield from planting season 3, which had more rain than first two seasons. C30, C60, and C90 represent plots receiving 30, 60, and 90 tons (dry weight) of compost per acre. F30, F60, and F90 represent plots receiving inorganic fertiliser at rates equal to amount of nitrogen provided by compost treatments. Control plots received no compost or fertilizer.

TABLE 7

Results for season 1 of Friedman test (n = 4) for crop yield versus treatments as blocks

Treatments/blocks	χ^2	p	Sums of ranks	Results
C30 vs. control	4.00	0.0455	C = 8, control = 4	C30 > control
F30 vs. control	4.00	0.0455	F = 8, control = 4	F30 > control
F30 vs. C30	1.00	0.3173	F = 5, C = 7	F30 = C30
C60 vs. control	4.00	0.0455	C = 8, control = 4	C60 > control
F60 vs. control	4.00	0.0455	F = 8, control = 4	F60 > control
F60 vs. C60	4.00	0.3173	F = 5, C = 7	F60 = C60
C90 vs. control	4.00	0.0455	C = 8, control = 4	C90 > control
F90 vs. control	4.00	0.0455	F = 8, control = 4	F90 > control
F90 vs. C90	1.00	0.3173	F = 5, C = 7	F90 = C90

Note: F = inorganic fertilizer; C = compost.

TABLE 8

Results for season 2 of Friedman test (n = 4) for crop yield versus treatments as blocks.

Treatments	χ^2	p	Sums of ranks	Results
C30 vs. control	1.00	0.3173	C = 7, control = 5	C30 = control
F30 vs. control	4.00	0.0455	F = 8, control = 4	F30 > control
F30 vs. C30	4.00	0.0455	F = 4, C = 8	F30 > C30
C60 vs. control	4.00	0.0455	C = 8, control = 4	C60 > control
F60 vs. control	4.00	0.0455	F = 8, control = 4	F60 > control
F60 vs. C60	1.00	0.3173	F = 5, C = 7	F60 = C60
C90 vs. control	4.00	0.0455	C = 8, control = 4	C90 > control
F90 vs. control	4.00	0.0455	F = 8, control = 4	F90 > control
F90 vs. C90	1.00	0.3173	F = 5, C = 7	F90 = C90

Note: F = inorganic fertilizer; C = compost.

TABLE 9
Results for season 3 of Friedman test (n = 4) for crop yield versus treatments as blocks

Treatments	χ^2	p	Sums of ranks	Results
C30 vs. control	4.00	0.0455	C = 8, control = 4	C30 > control
F30 vs. control	4.00	0.0455	F = 8, control = 4	F30 > control
F30 vs. C30	4.00	0.0455	F = 4, C = 8	F30 > C30
C60 vs. control	4.00	0.0455	C = 8, control = 4	C60 > control
F60 vs. control	4.00	0.0455	F = 8, control = 4	F60 > control
F60 vs. C60	1.00	0.3173	F = 7, C = 5	F60 = C60
C90 vs. control	4.00	0.0455	C = 8, control = 4	C90 > control
F90 vs. control	4.00	0.0455	F = 8, control = 4	F90 > control
F90 vs. C90	1.00	0.3173	F = 5, C = 7	F90 = C90

Note: F = inorganic fertilizer; C = compost

During season three, when planting coincided with the rainy season (September 2016 to December 2016), even though both compost and fertilizer were reapplied at the same rate as the year one, all plots performed poorly because intensive rain events washed the nutrients from both compost and fertilizer plots down through the soil matrix and out of the root uptake zone. However, fertilizer plots performed slightly better than compost plots under these conditions possibly due to the readily available nutrients within the soil solution at the time of uptake. During this 3-month period, Guam received 694 mm of rainfall (Weather Underground, 2016) compared to 523.2 mm in season one of the experimental periods.

It is worth noting that, the low yield from compost plots might have been caused by the high C:N ratio, resulting from depletion of soil nitrogen due to increased microbial activities which was enhanced by high moisture content of the soil during the intense rain events. Weed growth was also rapid on the compost plots during these intense rain events and might have aggravated the nitrogen depletion, thus contributed to the lower yield therefore aggressive weed growth. Furthermore, since the maize variety used in season three was short height variety (< 1.5 m), thus it was more vulnerable to competition from weeds. Effective weed management such as mulching therefore is the key factor (Knight *et al*. 2017) that should be considered during future research.

DISCUSSION

Crop Yield

During season one of this study (October 2013 to January 2014), compost-treated plots, produced slightly higher (although not statistically significant) maize than fertilizer-treated plots (Figure 5). Both compost and fertilizer plots produced statistically significantly higher yields than control plots.

During season two (June 2014 to February 2015), compost plots received no additional compost application, as a test of long-term carry-over from the treatment effect, however, fertilizer plots continued to receive same amount of inorganic fertilizer treatments as in season one. As expected, fertilizer plots produced significantly higher yield than untreated compost and control plots (Figure 6), but compost plots continued to produce higher yield (1.9 to 2.8 times) than the untreated control plots (Figure 6) throughout the experimental period.

During season three, which coincided with a rainy season (September 2016 to December 2016), both compost and fertilizer plots received same rate of treatment application as they did in season one. However, the low yield harvest from composted applied plots were believed to be resulted from the high C:N ratio of the compost at the time of application. Additionally, aggressive weed growth due to high moisture content resulted from intensive rain events might have negatively impacted the yield of the composted applied plots during the study period. Because the same maize variety was not available for the season three planting, the variety used for that season was therefore more vulnerable to competition from weeds resulting in low yield production. Effective weed management such as mulching is therefore a key factor (Knight *et al*. 2017), affecting yield that could be considered for future cases, following compost application in similar field studies.

Organic Matter

Compost plots maintained higher soil organic matter (SOM) content than did fertilizer plots throughout the study period, notably during the re-application of compost in season three. The higher SOM led to the carry-over effect with the yield being higher than that of control plots even during season two, when the compost was not re-applied. Compost also improved the physical properties of the porous soil of northern Guam by lowering soil bulk density (Figure 4) and increasing SOM. Higher SOM is known to increase soil-water and nutrient-holding capacity (cation exchange capacity) thereby, limiting leaching of nutrients (N, P) into the ground water.

Low SOM leads to high soil bulk density, negatively affecting plant growth and development and consequently having a negative impact on the crop yield. SOM contributes to soil structure that promotes better root penetration and proliferation. Application of composted organic waste to the porous soil of northern Guam decreased soil bulk density and increased SOM, benefiting plant root development, and contributing to plant growth and performance thus increasing the crop yield.

Bulk Density

Fertilizer and control plots showed higher bulk density (mean of 1.36 g/cm^3) than in compost treated plots (mean 1.16 g/cm^3), indicating that the application of composted organic waste can lower the bulk density thus improving physical properties of the soil under these treatments.

CONCLUSION

The idea that composted organic waste has agronomic value and could be used as a 'resource recovery' management strategy, sounds appealing and, in fact, has been shown to be of great benefit to soil quality and crop productivity on the island of Guam (Golabi *et al.* 2003). Guam also has limited landfill space and can benefit from reduced organic matter disposal via compost and composting. On the other hand, the SOM deficiency in most Guam soils can be alleviated by land application of compost for soil quality improvement and agricultural sustainability. At least initially, the added SOM can slow down leaching (Galsim *et. al.*, 2020), retain nutrients in the soil-water within the root zone that would otherwise drain down beyond the depth available to plant roots (Golabi *et al.* 2007).

Application of composted organic wastes on land also recycles nutrients and effectively recovers valuable resources that would otherwise be disposed of in the landfill as waste. Additionally, land application of composted organic waste in fact represents an important economic benefit in terms of 'resource recovery management' as well as soil improvement for agricultural sustainability in Guam and the other islands of Micronesia.

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