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Organic Amendments Increased Sweetpotato (Ipomoea batatas L.) Yield in a Calcareous Sandy Soil of Samoa

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Abstract

A five-month field experiment was conducted to investigate the effects of organic amendments on yields of two sweetpotato cultivars in a calcareous sandy soil of Samoa. The treatments consisted of three organic amendments; gliricidia, gliricidia + biochar, poultry litter, and a control, and two improved sweetpotato cultivars (IB/PH/03 and IB/PR/13). All amendments were applied at equivalent rate of 100 kg N ha^{-1} while biochar at 5 t ha^{-1}. Plots were arranged in a RCB design with four replicates. Results showed that all organic amendments significantly increased total storage root and marketable storage root yields, compared to yields of the control. Total marketable root yield was increased by 134, 118, and 294% over control in response to gliricidia, poultry litter, and gliricidia + biochar treatments, respectively. The highest yield, yield attributing parameters and nutrient uptake by storage root were recorded in gliricidia + biochar treatment, which appears to synergistically influence crop yield relative to organic amendments applied singly; a potential amendment for improving sweetpotato productivity in sandy calcareous soil. Cultivar IB/PH/03 performed better than IB/PR/13 on all measured crop parameters except for fresh weight of non-marketable root and percent dry matter content showing better potentiality for promotion under similar agro-environmental conditions.

Keywords: *Organic amendments, Biochar, Calcareous sandy soil, Sweetpotato root yield*

1. Introduction

Calcareous sandy soil is an inherent soil type to the entirety of Pacific atolls (for e.g. Tokelau, Tuvalu, Marshall Islands, and Kiribati), while in volcanic islands, such coastal soil constituted only a small but significant portion of the total arable land. Derived originally from calcareous-rich materials such as coral reef and other marine organisms, the limited availability of essential plant nutrients is the most serious constraint to food production under such soil (Morrison 1992; Stone *et al.*, 2000). Nitrogen (N) and potassium (K) deficiencies are common (Finlay, 1987a; Reddy and Chase, 1992) while phosphorus (P) and micronutrients particularly iron (Fe), zinc (Zn) and manganese (Mn) are unavailable due to low solubility caused by high soil pH as a result of the carbonate mineralogy (Morrison, 1992). The physical sandy texture of the soil promotes rapid drainage, low water holding capacity, and cation exchange capacity. Sometimes sub-soil compactness and rough-surfaces of the particles and their arrangement resist root penetration (Stone *et al.*, 2000). Based on these, calcareous sandy soil is considered unsuitable for intensive cropping (Finlay, 1987b; Reddy and Chase, 1992; Morrison, 1990; Stone *et al.*, 2000). Hence, it is naturally an infertile soil.

Calcareous sandy soil type is also found in Samoa especially in the coastal areas where they are developed from limestone sands (Wright, 1963). The prevalence of comparatively fertile soil types (latosols and lithosols) (Wright, 1963) resulted in these calcareous soils being unused or rarely used for cropping as this soil has many limitations. In the foreseeable future, however, land scarcity due to competition from human occupations and agricultural developments would mean such marginal soil must not be left unused especially when food security is an ensuing problem. To utilize this soil maximally, feasibly sound fertilizer schemes must be adopted. Apparently, it is folly to promote synthetic fertilizers in Samoa where farmers' purchasing powers are hampered by the exorbitant imported fertilizers (Hunter *et al.*, 1997; Chand, 2002) and the associated leaching problems. Therefore, amending the soil with organic fertilizers could be the best viable option.

Organic fertilizer under coralline soils has proven to increase yield in tomato (Reddy and Chase, 1995) under Samoa conditions. Similarly, in the Marshall Islands, the performance of cabbage under the organically treated soil was comparable to that on soil treated with chemical fertilizer (Deenik, 2003), attesting crop production is possible without the latter. The increasingly attractive organic farming in Samoa (SBS, 2016) is an indication of farmers opting for organic fertilizers. However, the fertilizing potentials of copious organic resources available are not known.

The effect of organic amendments on the yield of selected crops under Samoa common soils have been reported by several workers. For instance, gliricidia (*Gliricidia sepium*) was reported by Kidd and Taogaga (1985) to have increased taro yield by 54% when leaves were used as mulch. However, it did not improved taro yield in a four year alley cropping system (Rosecrance *et al.*, 1992). Poultry manure has been reported to significantly improve yield of maize (Siasau *et al.*, 2012; Chand *et al.*, 2013) and cabbage (Ruan, 2003; Prasad, 2004). Biochar, a relatively new and under-exploited amendment used as a mulching material improved nutrient uptake in taro (Anand, 2016). However, information on crop yield in response to these amendments on calcareous soil is scarce particularly under Samoa condition. Keeping in view of the above, a field study was conducted to test the effect of selected organic amendments on the yields of sweetpotato cultivars and to test the adaptability of two improved sweetpotato cultivars in a calcareous sandy soil in Samoa.

2. Materials and Methods

2.1. Site selection and land preparation

This study was conducted at a farm in Savaia on the island of Upolu, Samoa (Figure 1) in conjunction with a "Enhanced climate change resilience of food production systems in the Pacific Island countries and territories (PICTs)" project under the auspices of the United States Agency for International Development (USAID). A relatively small area along the coastline, conspicuously sandy in nature, was selected. This was a recent soil derived from limestone sand that normally has a brackish or saline water table (Wright, 1963). Based on the knowledge of Tusani Luasamotu (pers. comm., 2014), the soil which has not been used extensively for cropping had become an integral soil type in the farm after years of oceanic deposition and accumulation. Composite soil sample was collected and analysed following procedures adopted at the Alafua Central Laboratory, Samoa. Physico-chemical characteristics of the soil are presented in Table 1. The experimental area belongs to a tropical climate that receives an annual rainfall ranging from 2500 to 7000 mm and a mean temperature of range 24-29 °C. The field was manually cleared using bush knife while rakes were used to remove plant debris and stones. Plots sizes of 3 m x 2 m were prepared with digging forks and the sandiness of the soil made this task commendably less laborious. Plots were prepared with a one meter wide alleyway separating them.

2.2. Treatments and experimental design

This study employed a total of eight treatments made up of two improved cultivars of sweetpotato (IB/PH/03 and IB/PR/13) in factorial combination with four soil fertility treatments. The soil fertility treatments included three organic amendments: gliricidia (*Gliricidia sepium*), gliricidia + biochar, and poultry litter and a control.

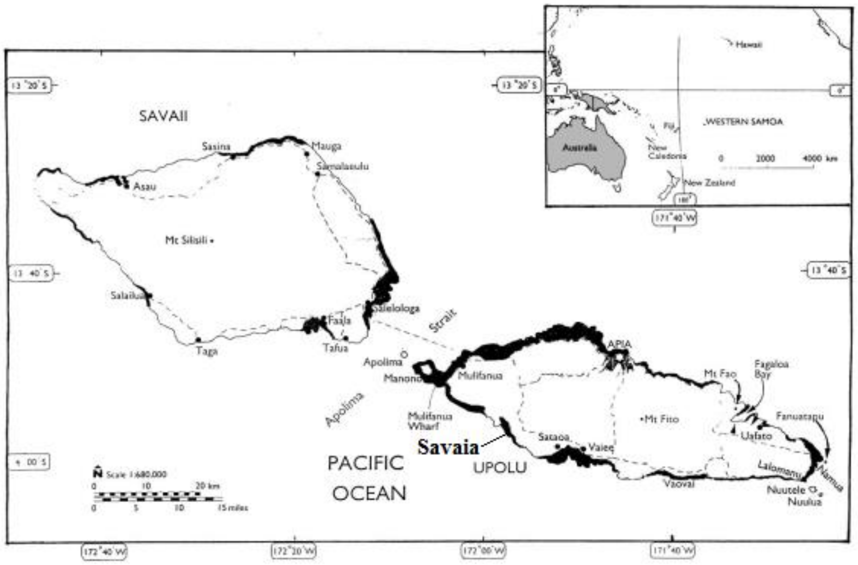

Figure 1. Savaia, Upolu, location of the on-farm study site.

Table 1. Characteristics of the experimental soil before planting.

Soil properties	Values	Methods	References
Bulk density (Mg m^{-3})	1.05	Core sampler	
Texture		Hydrometer	Bouyoucos (1962)
Clay (%)	14		
Silty (%)	8		
Sand (%)	78		
Textural class	Sandy loam		
Classification (USDA taxonomy)	Typic Tropopsamment		Russell (1990)
pH	7.90	1:5 (Soil:Water)	
OC (%)	7.57	$K_2Cr_2O_7$ Wet oxidation	Walkley and Blake (1934)
TN (%)	0.74	Semi-micro Kjeldhal	Blakemore *et al*. (1987)
Available P (mg kg^{-1})	11.1	$NaHCO_3$ extraction	Olsen *et al*. (1954)
CEC (cmol (+) kg^{-1})	34.8	Index Cation - NH_4OAc (pH 7)	Daly *et al*. (1984): Blakemore *et al*. (1987)
Exchangeable cation (cmol(+) kg^{-1})			
Ca	20.9		
Mg	1.38		
K	0.10		

The availability of gliricidia copiously grown as living hedgerow allowed its utilization in this study. It was interesting to discern of the farmers' anticipation of the end results because of the absolute zero awareness on the fertilizing potential of this readily available leguminous plant. Biochar, a relatively new amendment in Samoa was produced by pyrolysing coconut husk at the USP-SAFT (University of the South Pacific – School of Agriculture and Food Technology) using a simple hand-made retort oven. The oven (Figure 2) consisted of a 45 kg gas cylinder cut and inverted to fit in a 200-L drum and filled with dried coconut husk as the feedstock. Between the drum and the cylinder is the charring chamber where packed firewood was burnt from top to bottom. Perforation at the lower portion of the drum allows suction of air to maintain burning. With the aid of a hand-held compact Infrared thermometer with dual laser targeting, the maximum temperature ranged between 450-600 °C and charring often last at least 3 hours to the dying ember. The charred husk were fragmented in field by treading while enclosed in a sack; a viable pragmatic approach in the absence of a shredding equipment. The abundance of poultry litter at the USP-SAFT poultry unit permitted its deployment for this study as well. Table 2 shows some chemical characteristics of the organic amendments. The selection of sweetpotato was based on the fact that it is a hardy crop and adaptable to a wide range of marginal soils.

Except for biochar which was co-applied at 5 t ha^{-1}, all other soil fertility amendments were applied mainly as an N source at 100 kg N ha^{-1} equivalent rate. On dry matter basis, the equivalent quantities per hectare of poultry litter, gliricidia, and biochar applied were about 4.5 t, 3.5 t and 0.056 t, respectively. These were applied uniformly on assigned plots before incorporation by means of digging forks. A plot without amendment is deemed the farmer's practice and hereafter referred to as control. Treatment combinations were arranged in a factorial randomized complete block design with four replicates.

Table 2. Chemical characteristics of the organic amendments.

	Organic amendments		
Properties*	Poultry litter	Gliricidia	Biochar
Total N (%)	2.23	2.84	1.12
P (%)	1.38	0.22	-
Ca (%)	0.02	0.32	0.09
Mg (%)	0.45	0.35	0.13
K (%)	0.14	†	1.21
CEC (cmol/kg)	-	-	171.9

*Determined following Blakemore *et al*. (1987) and Daly *et al*. (1984); - not determined; † below detection limits.

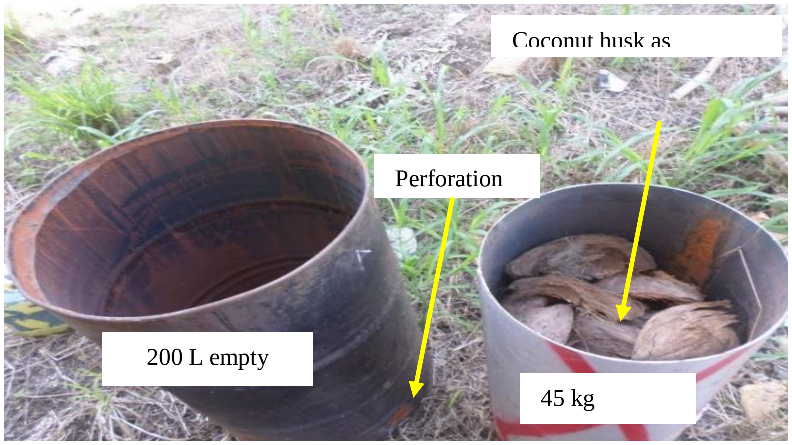

Figure 2. Pyrolysis oven consist of a 200 L drum and 45 kg cylinder for charring coconut husk.

Sweetpotato cuttings of 30 cm long comprising both vine tips and portions immediately below the vine tip were pre-conditioned in a shade and moist condition for 3 days to initiate rooting before planting (Nwinyi, 1991). A week following the incorporation of the organic amendments, rooted cuttings were planted with 2-3 nodes in the soil at a spacing of 40 cm between rows and 90 cm within rows of each plot. This spacing generated a planting density equivalent to 33,333 plants per hectare.

Manual weeding was done during the first four weeks after planting (WAP) to keep the plots weed-free. This was not required thereafter because of the effective smothering effect of the developing plant canopies. Earthing or hilling around the plant to facilitate aeration and for larger area for root development was done during 2-3 WAP. The plants were rain fed. Rainfall recorded during the study period is presented in Figure 3.

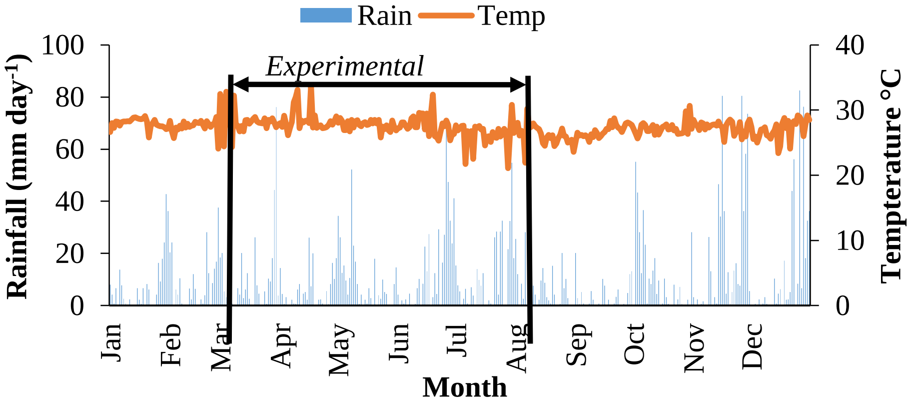

Figure 3. Daily rainfall and average temperature readings during the study period recorded by the closest weather station to the study area. Source: Samoa Meteorological Service.

2.3. Data collection and analyses

Harvesting was done on the 4th August, 2015, i.e. 20 WAP where fresh weight of marketable (100 g ≥) and non-marketable (< 100 g) roots were recorded using a top-plate balance. The number of roots were recorded by counting. Total storage yield refers to the combination of marketable and non-marketable yield, with the total number of roots is the aggregate count of marketable and non-marketable roots. Injured roots thought to be caused by rats or possibly hermit crabs were discarded. These data were recorded in field as all root yield except a small representative sample (for nutrient analysis) was given to the farmer in lieu of the farm rent. From the representative sample, a sub-sample of storage root were oven dried at 65 °C to constant weight to determine the dry matter (DM) content and NPK contents following Blakemore et al. (1987) and Daly et al. (1984). NPK uptake was determined by multiplying the percentage nutrient content by the dry matter yields.

All the data collected were subjected to analysis of variance (ANOVA) using a Statistical Tool for

Agricultural Research (STAR) software version 2.0.1 (STAR, 2014; Biometrics and Breeding Informatics, IRRI). Where a significant difference was detected, the least significant difference (LSD) test at P=0.05 was used to separate the treatment means.

3. Results and Discussion

3.1. Effect of organic amendments and sweetpotato cultivar on storage root yield

3.1.1. Marketable, non-marketable and total storage root

Effect of organic amendments and sweetpotato cultivars on marketable, non-marketable, and total storage root yield was significant ($P<0.05$) except cultivar influence on non-marketable storage root yield. The interaction effect of organic amendments and sweetpotato cultivars however, was insignificant. Thus, the effects of organic amendments were averaged over sweetpotato cultivars and effects of sweetpotato were averaged over organic amendment treatments. All the aforementioned yields of storage roots (t ha^{-1}) were significantly increased by the addition of organic amendments over control (Table 3). Gliricidia + biochar treatment produced the highest marketable, non-marketable and total storage root yield followed by gliricidia and poultry litter. The latter treatments had statistically similar marketable and total storage root yield, but are on par with the control with regards to the non-marketable storage root yield. The lowest marketable and total yield however, was produced by the control treatment. Total storage root yield was increased by 91.2, 98.1, and 227.4 % over control in response to the gliricidia, poultry litter, and the gliricidia + biochar treatments, respectively. Regarding the marketable yield, the magnitude of yield increased were 134, 118 and 294 %, respectively. Similar results were recorded by Haliru *et al.* (2015) attesting the significance of organic manure in improving total storage root yield over control.

High storage root yield of sweetpotato under the organically treated plots indicated that sweetpotato responded favourably to the application of organic. All the organic amendments resulted in increases in yield by more than two folds. The application of organic amendments provided the needed nutrients for the crop (Stathers *et al.*, 2005). All amendments were applied mainly as nitrogen source however; they also supplied other nutrients found in organic matter. Thus, the incremental nitrogen and other nutrients especially when available at the appropriate growth stages improved sweetpotato storage root yield (Bourke, 1985).

The greatest increase in yield was most highly favoured by the gliricidia + biochar treatment. Gliricidia and poultry litter when applied per se had comparatively similar coextensive results. However, when gliricidia was co-applied with biochar, the yield was drastically increased. It is appears that the manifold benefits of biochar hereafter discussed may have been influential under calcareous conditions.

First, it is widely appreciated that biochar is a highly porous organic matter with high surface area that when incorporated to the soil increases water holding capacity, CEC, sorption capacity and cation nutrients (Glaser *et al.*, 2002; Liang *et al.*, 2006; Hossain et al., 2017). The porous structure of the applied coconut biochar may have entrapped rapidly released nutrients from the decomposition of gliricidia thereby reducing the loss of nutrients through leaching and enhancing nutrient availability for plant utilization that would otherwise have leached out rapidly.

Second, 5 t ha^{-1} coconut biochar itself contains around 60 kg K ha^{-1}. Potassium is considered a very important nutrient for sweetpotato root formation and development (O'Sullivan, 1997; Siose and Guinto, 2017). Not all of the 60 kg K may have been released but results indicate that the amount released was enough to positively influence sweetpotato yields.

Third, one of the major problems to crop nutrition under such soil is water deficiency and is aggravated by its exceedingly sandy texture. Hernandez *et al.* (1965) estimated a required amount of water of about 18 mm/week in the early season and gradually increase to as much as 44 mm/week in midseason. This was amply supplied through rainfall during the study (Figure 3) especially with the early season. However, water supply is offset by high drainage losses. Through the application of organic amendments, water retention is perceived to have greatly improved. Water content of sandy soil was boosted under elevated organic matter content (Troeh and Thompson, 2005). Yield increase in sweetpotato has been also attributed to the improved soil water holding capacity when biochar was added (Yang *et al.*, 2015).

Fourth, application of biochar also improved physical and biochemical soil properties immensely (Asai *et al.*, 2009). Although the soil conditions were not quantitatively assessed during the study, improved conditions due to organic amendments may have played a central role leading to the increase in yield.

The average global sweetpotato yield according to FAOSTAT (2006) is 13.7 t ha^{-1}. Gliricidia + biochar treatment was the only treatment to have produced greater marketable roots, however, with regard to total yield, Control was exclusively below par. It is difficult to make serious comparisons as, so far, no similar studies have been carried out in Samoa.

Storage root yield in sweetpotato was also found to be significantly affected by the type of cultivar. Cultivar IB/PH/03 outperformed IB/PR/13 by three fold and two fold higher with respect to marketable and total root yield, respectively. However, both cultivars showed similar non-marketable root yield. The difference in yield is discernibly attributed to the genetic variation between the cultivars. The higher response of IB/PH/03 could be due to better nutrient use efficiency. Apparently, IB/PH/03 seems more adaptable than IB/PR/13 to calcareous sandy soils of Samoa.

3.1.2. Number of storage roots

The number of marketable roots increased in response to organic amendments, but only the gliricidia + biochar treatment produced statistically significantly higher number of roots compared to control (Figure 4). It is again likely that the complementary application of biochar to gliricidia favours the production of more storage roots perhaps through enhancing nutrient availability than the amendment applied singly. With respect to cultivars, IB/PH/03 was superior to IB/PR/13. Perhaps IB/PH/03 is better suited to the environmental condition of the experimental site.

Table 3. Storage root yield (t ha^{-1}) as affected by organic amendments and sweetpotato cultivars.

Treatments	Marketable	Non-marketable	Total
Organic amendments			
Control	5.0c	2.3b	7.3c
Gliricidia	11.7b	2.2b	13.9b
Gliricidia + biochar	19.7a	4.1a	23.8a
Poultry litter	10.9b	3.5ab	14.4b
LSD (0.05)	3.44	1.46	4.09
Cultivars			
IB/PH/03	17.8a	2.6a	20.4a
IB/PR/13	5.8b	3.5a	9.3b
LSD (0.05)	2.43	ns	2.89
Interaction	ns	ns	ns

Within a column, treatment means with similar letters are not significantly different at P=0.05; ns = not significant.

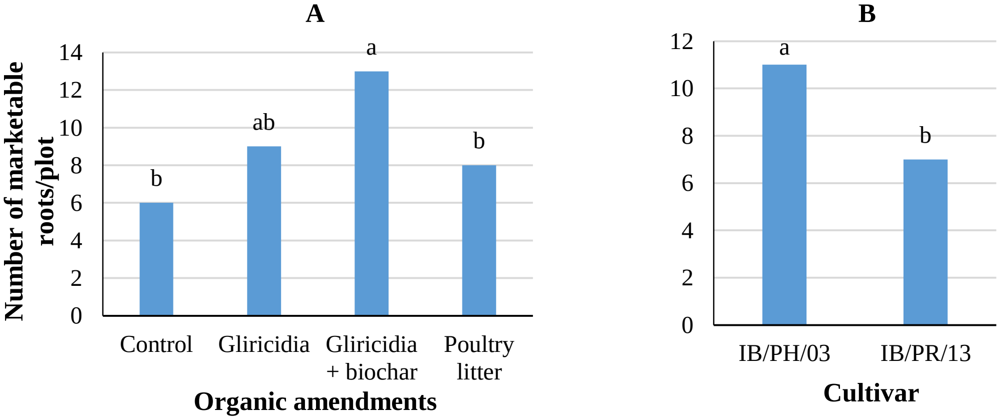

Figure 4. Number of marketable storage roots as affected by the main effect of organic amendments (**A**) and sweetpotato cultivar (**B**). Bars with similar letters are not significantly different at *P=0.05*.

A significant interaction effect was found in regard to the number of non-marketable and total number of storage roots (Table 4). Both cultivars responded similarly to all amendments except IB/PR/13 to the gliricidia + biochar amendment, where the greatest count were recorded for both the root types.

Production of higher number of storage roots is indicative of sweetpotato's favourable response to the application of organic amendments. Increased number of sweetpotato storage roots as affected by organic amendments was also reported by Hartemink (2003) and Sowley *et al*. (2015). The type of amendments affected the number produced with gliricidia + biochar noted to be the most effective especially at the marketable root, where profitability is largely determined. The higher number of marketable roots in IB/PH/03 may be attributed to genetic factors, is considered more profitable than IB/PR/13. This is because the number of non-marketable roots of the latter cultivar constituted 77 % of the total number of roots against 50 % that of the former cultivar. However, the latter cultivar may produce more if harvest is delayed.

Table 4. The effect of organic amendments on the number of non-marketable roots and total number of storage roots.

Treatments	IB/PH/03	IB/PR/13
Number of non-marketable roots per plot		
Control	11.3aA	19.8bA
Gliricidia	12.0aA	18.3bA
Gliricidia + biochar	9.50aB	38.3aA
Poultry litter	10.0aB	26.8bA
LSD (0.05)	12.01	12.01
Interaction	ns	*
Total number of storage roots per plot		
Control	20.8aA	23.0bA
Gliricidia	23.8aA	25.0bA
Gliricidia + biochar	21.8aB	51.3aA
Poultry litter	22.3aA	29.3bA
LSD (0.05)	14.7	14.7
Interaction	ns	*

*Within a column, treatment means of root numbers with similar lower-case letters are not significantly different at P=0.05. Between columns, treatment means with similar upper-case letters are not significantly different at P=0.05; ns = not significant; * = significant.*

3.1.3. Storage roots DM contents and DM yields

DM percentage in sweetpotato root was unaffected by the organic amendments but the total root DM yield in t ha^{-1} varied significantly with the maximum yield attained with the gliricidia + biochar treatment (Table 5). Gliricidia and poultry litter scored the second highest while the control had the lowest. Respectively, gliricidia + biochar, poultry litter, and gliricidia increased DM yield by 235 %, 105 %, and 85 % over control treatment. This finding categorically proved that organic amendment increased DM in sweetpotato roots and corroborates finding of Kelm *et al*. (2001), where root DM was greatly reduced under N stress conditions as reflected at the Control treatment of this study. Between cultivars, percentage DM was significantly higher for the IB/PR/13 cultivar than IB/PH/03 cultivar attesting higher moisture content of the latter. On the other hand, the latter surpassed its counterpart in terms of total root DM yield in t ha^{-1}.

3.2. Effects of organic amendments and sweetpotato cultivars on storage root NPK uptake

The application of organic amendments increased nutrient (N, P, and K) uptake of storage root, with the highest effect significantly pronounced with the gliricidia + biochar treatment across all the nutrient parameters (Table 6). N and K uptake by the other two organic treatments (gliricidia, poultry litter) were higher but statistically on par with control. However, the latter had the least significant P uptake across all treatments. Supplementing nutrients via organic amendments was influential in augmenting nutrient levels thereby enhancing nutrient uptake. Like the above measured parameters, the amendment type largely influences N, P, K uptake by roots. It is important to note that nutrient uptake however, was less effective when amendment is applied singly, adducing improved nutrient use efficiency when biochar is applied complementarily with gliricidia. This could be attributed to the nutrient entrapment capacity of biochar as earlier discussed and the fact that it generally has greater specific surface area than clay (Downie *et al*., 2009) for greater nutrient adsorption.

All treatments revealed N and K levels higher than the P values, however only gliricidia and gliricidia + biochar had K levels higher than N. The nutrient adsorption capacity of the soil was greatly enhanced following biochar application to explain the higher nutrient availability particularly K (Rogovska *et al*., 2011; Jindo *et al*., 2012). Given the increased CEC due to biochar (Table 2), it can be therefore rationally asserted that higher nutrient uptake may be attributed to biochar abating the nutrient leaching dynamics of the soil and supplying more for plant uptake.

3.3. Correlation between total root yield, yield attributes, and nutrient uptake

Except for non-marketable yield, total root yield (t ha^{-1}) was significantly associated with genotypic traits like marketable yield (t ha^{-1}), dry matter (% and t ha^{-1}) and nutrient (N, P, and K) uptake (Table 7). The strongest association between marketable yield and total root yield (r = 0.98**) indicates that the latter is positively affected by the former attribute and vice versa. Equally, higher dry matter yield (t ha^{-1}) was emanated from higher total yield (r = 0.97**). Total root yield was also highly correlated with the uptake of P (r = 0.92**), but moderately and weakly associated with the uptake of N (r = 0.77**) and K (r = 0.51**), respectively. It can be asserted that the higher the total yield, the greater the dry matter and subsequently higher nutrient contents. Comparable results were reported by

Engida *et al*. (2006) where higher dry matter is reportedly correlates with total root yield. On the contrary, only the percent dry matter is negatively correlated with total yield; an attribute large controlled by genetic factors and would not merit for high yield production and industrial utilization for starch production. This result is also supported by others (Kamalam *et al*., 1977 and Engida *et al*., 2006).

Total root yield was not found associated with total root number and number of non-marketable roots but with the number of marketable roots (r = 0.72**). Comparatively, the corresponding correlation coefficient in marketable root yield (t ha^{-1}) is higher (r = 0.98) implying that the genotypic factor influence total root greater than this traits, tallying with findings by Gedamu *et al*. (2010).

Table 5. Sweetpotato content (%) and dry matter yield (t ha^{-1}) as affected by organic amendments and

Treatments	**(%)**	**(t ha^{-1})**
Organic amendments		
Control	34.8a	2.32c
Gliricidia	33.6a	4.28b
Gliricidia + Biochar	33.0a	7.76a
Poultry litter	34.5a	4.76b
LSD (0.05)	ns	1.50
Cultivars		
IB/PH/03	30.0b	6.13a
IB/PR/13	37.9a	3.43b
LSD (0.05)	2.32	1.06
Interaction	ns	ns

Within a column, treatment means with similar letters are not significantly different at P = 0.05; ns = not significant.

Table 6. Nutrient uptake (kg ha^{-1}) by storage root as affected by organic amendments and sweetpotato cultivars.

Treatments	**N**	**P**	**K**
Organic amendments			
Control	8.46b	3.5c	7.6b
Gliricidia	11.5b	6.1b	19.2b
Gliricidia + Biochar	21.7a	10.5a	35.5a
Poultry litter	13.6b	6.6b	12.2b
LSD (0.05)	7.62	2.19	11.8
Cultivars			
IB/PH/03	16.8a	9. 1a	26.7a
IB/PR/13	10.9b	4.13b	10.5b
LSD (0.05)	5.39	1.55	8.38
Interaction	ns	ns	ns

Within a column, means of treatment type with similar letters are not significantly different at P=0.05.

Table 7. Correlation between Total Root yield and other harvest parameters.

Parameters	**Correlation (r) values**
Marketable yield	0.98**
Non-marketable yield	0.26ns
Dry matter (t ha^{-1})	0.97**
Dry matter (%)	-0.60**
N uptake	0.77**
P uptake	0.92**
K uptake	0.51**
Total root number	0.07ns
Marketable root number	0.72**
Non-marketable root number	-0.20ns

*** = significant at P=0.01* (2-tailed)*; * = significant at P=0.05* (2-tailed)*; ns = not significant*.

4. Conclusions

The application of organic amendments at 100 kg N ha^{-1} increased total root yield of sweetpotato between 13.9 – 14.4 t ha^{-1} when applied singly and 23.8 h ha^{-1} when biochar was co-applied. Yield attributes and nutrient uptake were also improved greatly by the addition of biochar to gliricidia to prove that it was the best amendment. The optimum ratio and rate of gliricidia and biochar and the underpinning high yielding mechanism however needs to be investigated for the sensibly sound application of this technology in the future. The outstandingly higher yield of the cultivar IB/PH/03 over IB/PR/13 proves of its better adaptability to such soil condition. The findings proffer recommendation of this cultivar under similar agro-environment within the region and abroad but needs multi-locational field trial.

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References

Anand, S. 2016. *Developing a taro (Colocasia esculenta) production system based on genotype and fallow system for economic and environmental sustainability under local conditions in Samoa*. PhD Thesis, The University of the South Pacific, School of Agriculture and Food Technology. Suva, Fiji. p.335.

Asai, H., Samson, K. B., Stephan, M. H., Songyikhangsuthor, K., Hommar, K., Kiyono, Y., Inoue, Y., Shiraiwa, T. and Horie, T. 2009. Biochar amendment techniques for upland rice production in North Laos: 1. Soil physical properties, leaf SPAD and grain yield. *Field Crop Research* **111**, 81-84.

Blakemore, L. C., Searle, P. L., and Daly, B. K. 1987. *Methods for Chemical Analysis of Soils. New Zealand Soil Bureau Scientific Report 80*. New Zealand Soil Bureau, p.103.

Bourke, R. M. 1985. Influence of nitrogen and potassium on growth of sweetpotato in Papua New Guinea. *Field Crop Research* **12**, 363-376.

Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal* **54**, 464-465.

Chand, K. 2002. Samoa. http://www.apipnm.org/swlwpnr/reports/y_pa/zws/ws.htm (accessed on 23rd June, 2015).

Chand, S., Tokai, J., Kumar, P. and Nakadrudru, L. 2013. *Response of maize to various rates of poultry manure application on Moamoa series*. B.Agric. Thesis, The University of the South Pacific, School of Agriculture and Food Technology, Samoa.

Daly, B. K., Manu, V. T. and Halavatau, S. M. 1984. *Soil and plant analysis methods for use at the Agricultural Research Station, Vaini, Tonga*. New Zealand Soil Bureau Laboratory Report AN2, New Zealand.

Deenik, J. L. 2003. *Correcting soil nutrient deficiencies with organic materials in the atoll soils of the marshal islands*. PhD Thesis, University of Hawaii.

Downie, A., A. Crosky and P. Munroe. 2009. Physical properties of biochar. In: J. Lehmann and S. Joseph (Ed) "*Biochar for environmental management: science and technology*" Earthscan, p.13-32.

Engida, T., Devakara Sastry, E. V. and Nigussie, D. 2006. Correlation and path analysis in sweetpotato and their implications for clonal selection. *Journal of Agronomy* **5**, 391-395.

FAOSTAT 2006. FAO Statistic Database. URL http://apps.fao.org/ accessed on 7th April, 2016.

Finlay, J. R., 1987a. Applying fertilizer on atolls. *Alafua Agricultural Bulletin* **12**, 89-92.

Finlay, J.R., 1987b. Comparison of four nitrogenous fertilizers on maize (*Zea mays* L.) in an atoll environment. *Alafua Agricultural Bulletin* **12**, 21-24.

Gedamu, Y., Belay, G. and Dechassa, N. 2010. Genotypic and phenotypic correlations of root yield and other traits of orange-fleshed sweet potatoes (*Ipomoea batatas* (L.) Lam.). *Journal of the Drylands* **3**, 208-213.

Glaser, B., Lehmann, J. and Zech, W. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal – A review. *Biology and Fertility of Soils* **35**, 219-230.

Haliru, M., Dikko, A. U., Audu, M. and Aliyu, I. 2015. Effect of cow dung on soil properties and performance of sweetpotato in Sudan Savanna, Nigeria. *International Journal of Plant and Soil Science* **5**, 212-216.

Hartemink, E. A. 2003. Integrated nutrient management research with sweetpotato in Papua New Guinea. *Outlook on Agriculture* **32**, 173-182.

Hernandez, T. P., Hernandez, T. P., Miller, J. C. and Jones, L. G. 1965. The value of irrigation in sweetpotato production in Louisiana, *La. Agric. Exp. Stn. Bull*. 607.

Hossain, M. A., Strezov, V., Akter, F., Kader, M, A. and Solaiman, Z. M. 2017. Impact of biochar on soil fertility and behaviour of xenobiotic in soil. In: Hashmi, M. Z., Kumar, V. and Varma, A. (eds.) *Xenobiotics in the Soil Environment*: Monitoring, Toxicity and Management. Springer International Publishing, p.299-318.

Hunter, D. J., Yapa, L. G. G. and Hue, N. V. 1997. Effects of green manure and coral lime on corn growth and chemical properties of an acid Oxisol in Western Samoa. *Biology and Fertility of Soils* **24**, 266-273.

Jindo, K., Suto. K., Matsumoto, K., Garcia, C., Sonoki, T. and Sanchez-Monedero, M. A. 2012. Chemical and biochemical characterization of biochar-blended composts prepared from poultry manure. *Bioresource Technology* **110**, 396-404.

Kamalam, P., Biradar, R. S., Hrishi, N. and Rajendran, P. G. 1977. Path analysis and correlation studies in sweetpotato (*Ipomoea batatas* Lam.). *Journal of Root Crops*, **3**, 5-11.

Kidd, T.J. and Taogaga, T. 1985. Nitrogen fixing trees as green manure for upland taro in Western Samoa. *Nitrogen Fixing Tree Research Reports* **3**, 67-68.

Kelm, M., Bruck, H., Hermann, M. and Sattelmacher, B. 2001. *Plant productivity and water use efficiency of sweetpotato (Ipomoea batatas) as affected by nitrogen supply*. Program Report 1999-2000. CIP, International Potato Center, Lima, p.273-279.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J. O., Thies, J., Luizao, F. J., Petersen, J. and Neves, E. G. 2006. Black carbon increases cation exchange capacity in soils. *Soil Science Society America Journal* **70**, 1719-1730.

Morrison, R.J. 1990. Pacific atoll soils: chemistry, mineralogy and classification. *Atoll Research Bulletin* **339**, 1-25.

Morrison, R.J., 1992. Soil physical and chemical limitations to increased agricultural production on atoll soils. In: Chase, R.G. (ed.), *A Review of Agricultural Development in the Atolls, Papers*

Presented at the Workshop on Developing an Agricultural Research Program for the Atolls, Pacific Harbour, Fiji, 19–23 Nov., 1990. University of the South Pacific, Apia, Western Samoa, pp. 27-36.

Nwinyi, S. C. O. 1991. Preplanting method and duration of storing sweetpotato (*Ipomoea batatas* (L.) Lam) shoot cutting planting materials for increased tuber yield. *Tropical Science* **31**, 1-7.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. 1954. *Estimation of available phosphorus in soils by extraction with sodium biocarbonate*. USDA Department Circular 939, USA.

O'Sullivan, J. N., Asher, C. J. and Blamey, F. P. C. 1997. *Nutrient disorders of sweetpotato*. ACIAR Monograph No 48, Canberra, Australia.136.

Prasad, I. C. 2004. *Effects of chicken manure and inorganic fertilizer (urea) on the growth, yield and yield components of Chinese cabbage (Brassica chinensis) var. Pak Choi under Samoa field conditions*. B. Agric. Thesis, The University of the South Pacific, School of Agriculture and Food Technology, Samoa.

Reddy, M. and Chase, R. J. 1992. Preliminary studies on nutrient leaching of N and K fertilizers applied to coralline soils. *Journal of South Pacific Agriculture* **1**, 27-32.

Reddy, M. and Chase, R. J. 1995. Effect of organic manures on tomato yield grown on coralline soil. *Journal of South Pacific Agriculture* **2**, 49-52.

Rogovska, N., Laird D., Cruse R., Fleming P., Parkin T. and Meek D. 2011 Impact of biochar on manure carbon stabilization and greenhouse gas emissions. *Soil Biology and Biochemistry* **75**, 871-879.

Rosecrance, R. C., Rogers, S. and Tofinga, M. 1992. Effects of alley cropped *Calliandra calothyrsus* and *Gliricidia sepium* hedges on weed growth, soil properties, and taro yields in Western Samoa. *Agroforestry Systems* **19**, 57-66.

Ruan, R. N. 2003. *The effects of chicken manure on yield of Chinese cabbage* (*Brassica chinensis*). B. Agric. Thesis, The University of the South Pacific, School of Agriculture and Food Technology, Samoa.

Russell, P. (Ed). 1990. *Land resource planning study: Western Samoa*. Asian Development Bank TA NO. 1065 – Sam Final Report. Lower Hutt, New Zealand, 147.

SBS (Samoa Bureau of Statistics). 2016. *Agricultural Survey 2015 Report*. Samoa Bureau of Statistics, Government of Samoa, pp.100.

Siasau, H., Peioneti, L., Mele, F. and Nomipa, N. 2012. *The effect of organic and inorganic fertilizer and their combination on the growth rate of maize* (*Zea mays*). B. Agric. Thesis, The University of the South Pacific, School of Agriculture and Food Technology, Samoa.

Siose, T. K. and Guinto, F. G. 2017. Performance of improved sweetpotato (*Ipomoea batatas* L.) cultivars under different soil types of Samoa. *South Pacific Journal of Natural and Applied Science* **35**, 1-9.

Sowley, E. N. K., Neindow, M. and Abubakari, A. H. 2015. Effect of poultry manure and NPK on yield and storability of orange-and white-fleshed sweet potato (*Ipomoea batatas* (L.) Lam). *ISABB-Journal of Food and Agriculture Science* **5**, 1-6.

STAR, version 2.0.1 2014. *Biometrics and Breeding Informatics*, PBGB Division, International Rice Research Institute, Los Baños, Laguna.

Stathers, T., Namanda, S., Mwanga, R. O. M., Khisa, G. and Kapinga, R. 2005. *Manual for sweetpotato integrated production and pest management farmer field schools in Sub-Saharan Africa*. International Potato Centre, Kampala, Uganda. ISBN 9970-895-01-X FAO IPPM FFS PROGRAMME, 168 + xxxipp.

Stone, E. L., Migvar, L. and Robison, W. L. 2000. *Growing plants on atoll soils*. UCRL-LR-137517 U.S. Department of Energy, Lawrence Livermore National Laboratory. University of California, Livermore, CA.

Troeh F. R. and Thompson L. M. 2005. *Soils and soil fertility*. 6th Edn. Blackwell Publishing: Ames, IO, USA.

Walkley, A. and Blake, I. A. 1934. An examination of the Degtjareff method for determining organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29-38.

Wright, A. C. S. 1963. *Soils and land use of Western Samoa*. New Zealand Soils Bureau, Bulletin. 22.

Yang, Y., Ma, S., Zhao, Y., Jing, M., Xu, Y. and Chen, Y. 2015. A field experiment on enhancement of crop yield by rice straw and corn stalk-derived biochar in Northern China. *Sustainability* **7**, 13713-13725. DOI: 10.3390/su71013713.

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