Influence of Selected Cover Crops and Biochar on the Yield Advantage of Two Taro (Colocasia esculenta) Cultivars in Samoa

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Abstract: On farm trials were conducted to compare dry matter yields and nutrient uptake of selected tropical cover crops and biochar application on different Samoan inceptisols. Consequent improvements in corm yield of two cultivars *Samoa 1* and *Samoa 2* were determined. Plant analyses showed that the N and P contents of erythrina was grossly higher than mucuna cover. Yet, *Mucuna pruriens* resulted in the highest nutrient buildup over the six month fallow period. Yield data suggests that mucuna with low rates of complete fertilisers can help maintain optimum taro yields under the shortened fallow durations. However, it appears that the yield responses of the taro crop to fallow treatments are site-specific.

Keywords: Fallow, Cover crop, Nutrient uptake

Introduction: In the Pacific Islands, taro has always been richly woven into the fabric of life, being a major sources of major sources of dietary energy for many island people (Guinto *et al.*, 2015). Intensification of production to meet food security and economic aspirations leads to the rapid soil degradation in the pacific islands. A sustainable crop production system must, therefore, adopt an ecological approach, using balanced nutrient inputs from inorganic, organic and biological sources (Wittwer *et al.*, 2017).

Cropping systems involve yearly sequences and special arrangements of crops, or fallow on a given area. Fallowing has been a valuable practice for exploring nutrient dynamics and overall assessment of fertilization (Shahid *et al.* 2016). The importance of cover crop and leguminous fallow in improving productivity of subsequent crops through soil mineral N contributions has been well documented (Fageria *et al.*, 2005; Baligar and Fageria, 2007; Gusti *et al.*, 2015; De Borja 2017). In addition, cover crops provide a variety of important agro-ecological services and improve the resilience of annual cropping systems, some of which includes soil organic carbon (SOC) sequestration (Olson *et al.*, 2010); improved phosphorus availability (Dube *et al.*, 2014); crop nutritional benefits, suppression of plant parasitic nematodes (Abiodun *et al.*, 2016); as well as other bacterial pathogens (Neiunna, 2016). Biochar incorporation lead increases in soil pH, total C, N, S, as well as exchangeable K, Ca, Mg and cation exchange capacity have been observed (Carter *et al.*, 2013); while a decline in the exchangeable Na has been reported in the same study.

Shifting cultivation with short fallow periods is an important form of land use system in the pacific island countries (Maathuis and van Meer, 2003). A quantitative evaluation of cover crops can provide the foundation for improvement in selecting organic practices to achieve taro's maximum yield potential under such systems. The use of biochar in agriculture has been well documented elsewhere in the world (Yang *et al.*, 2017); however, its use in pacific agriculture has been obscure.

Methodology

Study area and trials: This multi-location field trial was conducted at three different sites in Samoa (15-17° S and 171-173° W). Two leaf

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blight resistant taro cultivars (*Samoa 1* and *Samoa 2*) were grown under six fallow practices (Table 1) after a fallow duration of six months over three sites in 2014: Salani, Upolu, a high rainfall site (4,959 mm); Safaatoa, Upolu, receiving a comparatively lower annual rainfall (3,418 mm) and Siufaga, Savaii, (3,989 mm). The experimental design employed was a split plot arrangement in four randomised blocks with the six fallow practices randomly assigned as the main plots and the two cultivars as the sub plots.

Plant culture and management: After six month of fallow duration, vegetation under all the systems was sprayed with a systemic herbicide. Eight plants of each of the two cultivars of taro were planted using uniform size suckers in each of the net split plots within each fallow treatment at a spacing of 1m x 1m. After five and ten weeks of planting, the N.P.K treatment was applied as two split applications. Hilling and weeding was carried out across all plots.

Data collection: Destructive sampling using 0.5m x 0.5m quadrats was employed to determine the total dry matter yields (t/ha) of all the cover crop vegetation. Samples of fully developed young leaves were collected at six months of age (before herbicide spraying) and were oven dried to a constant weight at 65°C for determination of their dry matter yield, nutrient concentration and nutrient uptake. Nitrogen, phosphorus and potassium were determined after Kjeldahl digestion method for plant samples as described by Blakemore *et al.* (1987) and Daly *et al.* (1984) while Ca, Mg, Zn, Fe, Mn, and Cu by atomic absorption spectrophotometry (Chapman and Prat, 1961; Prasad and Spiers, 1978). Nutrient contents were calculated as the product of dry matter content and tissue nutrient concentration. Nutrient uptake was calculated by multiplying the percentage nutrient content by the dry matter yields, expressed as kg/ha. The taro crop was harvested at 8 months and yields were expressed as t/ha of fresh corm weight.

Statistical analysis: The biomass and nutritional composition data were analysed using ANOVA for randomised complete block design. The yield data from all the three sites was subjected to a nested classification analysis of variance for unbalanced designs, where blocks were nested into locations; the six fallow practices were nested into blocks and the two cultivars were nested into fallows. Mean comparisons were carried out using least significant differences (LSD). All the data analyses were carried out using the Genstat statistical software package (VSN International Ltd., 2011).

Discussion of results: The dry matter yields (t/ha) of all the fallow biomass and their nutrient uptake is given in Table 2. Mucuna biomass significantly out yielded all the other fallow cover crops across all the three sites. This can be ascribed to the inherent vigorous growth characteristic as well as its ability to fix atmospheric nitrogen biologically. Goh and Chin (2007) and Ngome *et al.* (2011) concluded that mucuna fallow crop fixed 70% of atmospheric N through biological symbiosis while the remaining was thought to have been taken up from the soil. However, Chikowo *et al.* (2004) stated that mucuna fallow fixed 96% of nitrogen. Sanginga *et al.* (2001) found that 91% of the total N was fixed by mucuna cover crop.

Tissue analyses revealed that the N and P contents of erythrina was higher than the mucuna cover across all three sites. However, due to lower biomass accumulations, total uptake of N and P was significantly much lower than the mucuna cover (Table 2). Since, the nutrient uptake of mucuna across all the sites were very high (196-700 kg N/ha), it is rational to assume that at taro harvesting time (eight months after spraying the fallow crop), almost all the N contained in the mucuna biomass has been mineralised. This can be attributed to the low C:N ratio of 11:1 for mucuna. Comparable findings were reported by Ibewiro *et al.* (2000) and Ruhlemann and Schmidtke (2016) showing that mucuna decomposition can be quite fast, losing 60% of its biomass within the first 28 days of decomposition while releasing up to 174 kg N/ha during that time period. The C:N ratios for erythrina, grass and biochar were 20:1, 25:1 and 70:1, respectively. These comparatively higher C:N ratios coupled with significantly lower biomass production than mucuna can be linked to much lower N inputs under the fallow systems.

Prominently, biochar supported vegetation resulted in higher uptake of K than all the fallow practices at the two biochar treated sites on the island of Upolu.

Significant concentrations of Mg and the analysed micronutrients (Fe, Mn, Cu and Zn) were also observed for the biochar supported vegetation in the high rainfall zone only. Generally, nutrient uptake was significantly higher under mucuna fallow systems across all the sites, owing to the higher biomass production, comparatively.

Fresh taro corm yields: The fresh taro corm yield data from the three sites highly significant ($P<0.001$) differences between sites, with the Salani site out yielding the other two sites (Figure 1). This can partially be attributed to the relatively higher amount of annual rainfall received by the Salani site (4,959 mm) as opposed to the Safaatoa (3,418 mm) and Siufaga (3,989 mm) sites. In addition, inherent soil fertility may have had a large influence on these yield variations.

Significant difference was also found ($P<0.05$) between the mean yields of two cultivars within the same fallow treatment, with cultivar Samoa 2 out yielding cultivar Samoa 1. Fallows within a site were also highly significant ($P<0.05$) with regards to the mean corm yield of taro produced over the three sites (Figure 1).

The six month cover crop fallow practice with mucuna together with modest application (200 kg/ha) of complete fertiliser (NPK 12-5-20) to the taro crop, that is a corresponding supplementation of 24 kg N/ha, 10 kg P/ha and 40 kg/K/ha, resulted in higher ($P<0.001$) mean yields, out yielding all the fallow practices except for taro grown under the mucuna with no fertiliser supplementation. Grass fallow supplemented with 400 kg/ha of complete fertiliser, (that is, 48 kg N/ha, 20 kg P/ha and 80 kg/K/ha) and the biochar fallow treatments did not differ significantly from each other; however, they significantly out - yielded the grass fallow.

This indicated that reasonable taro yields can be obtained under mucuna fallows with no supplementation as opposed to grass fallows with 400 kg/ha of complete fertiliser supplementation and biochar additions during fallow periods increases taro yields of the succeeding crop. This also shows that improved fallows are better than the traditional practice.

Conclusion: Analyses of all the cover crops for their nutrient concentrations and uptake showed that while generally the nutrient concentration of erythrina was significantly higher than that of Mucuna, the latter had higher nutrient accumulation over the six month fallow duration, owing to its comparatively higher biomass production over all the three sites. This was well reflected on the taro yields for Salani and Siufaga sites (high rainfall zones), where biomass production was comparatively higher. The yield of taro under mucuna with no supplementation of any fertiliser was not significantly different from taro grown under traditional grass with the crop being supplemented by the recommended rate of 400 kg/ha of complete fertiliser. This affirms that optimum taro yields can be obtained under mucuna fallow only without any additional inputs of chemical fertilisers. Comparable yields under biochar fallow can be attributed to the biochar fallow to enhance appreciable quantities of K uptake.

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Table 1. The Fallow Treatments

Fallow treatment	Treatment description
Farmer's practice	Natural grass vegetation with the biomass decomposed as mulch.
Mucuna	*Mucuna pruriens* propagated by seeds planted at 1m x 1m spacing. The entire biomass decomposed as mulch.
Erythrina	Erythrina subumbrans propagated by cuttings of 1m in length and planted at a spacing of 1m x1m. Biomass and residues decomposed as mulch.
Mucuna + 200 kg/ha N.P.K	*Mucuna pruriens* plus N:P:K (12-5-20) applied to the taro crop at a rate of 200 kg/ha in two split applications at 5 and 10 weeks after planting.
Farmer's practice + 400 kg/ha N.P.K	Natural grass vegetation plus N:P:K (12-5-20) applied to the taro crop at a rate of 400 kg/ ha in two split applications at 5 and 10 weeks after planting.
Biochar	Biochar produced from coconut shells incorporated at the beginning of the six month fallow period, at a rate of 15 t/ha. Vegetation during the fallow was incorporated.

Table 2. Dry matter yields and nutrient uptake by the fallow crops over the three sites

Site	Fallow	Dry matter yield (t/ha)	Nutrient uptake								
			Macronutrient (kg/ha)					Micronutrient (kg/ha)			
			N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Salani	Grass	8.21 *b*	78.77 *c*	12.31 *b*	105.02 *b*	25.44 *bc*	46.77 *b*	63.81 *b*	2.83 *b*	0.15 *b*	0.40 *b*
	Mucuna	22.11 *a*	486.31 *a*	35.37 *a*	305.05 *a*	170.21 *a*	75.16 *a*	140.45 *a*	5.18 *a*	0.57 *a*	0.73 *a*
	Erythrina	8.13 *b*	196.75 *b*	26.02 *a*	152.03 *b*	66.67 *b*	46.34 *b*	3.39 *c*	1.02 *c*	0.10 *b*	0.34 *b*
	Biochar	6.50 *b*	74.75 *c*	11.05 *b*	142.35 *b*	16.90 *c*	52.00 *b*	96.60 *b*	3.11 *b*	0.19 *b*	0.60 *ab*
	LSD (5%)	6.98	117.4	13.47	84.9	43.60	22.07	41.54	1.43	0.19	0.29
Safaatoa	Grass	7.62 *b*	89.95 *c*	14.48 *b*	83.09 *b*	50.31 *bc*	34.30 *b*	38.30 *b*	1.58 *b*	0.15 *b*	0.56 *a*
	Mucuna	17.85 *a*	408.65 *a*	30.34 *a*	215.92 *a*	219.49 *a*	71.38 *a*	127.13 *a*	4.34 *a*	0.51 *a*	0.65 *a*
	Erythrina	8.13 *b*	256.91 *b*	24.39 *ab*	98.37 *b*	113.82 *b*	49.59 *ab*	1.38 *b*	1.33 *b*	0.18 *b*	0.33 *b*
	Biochar	10.87 *b*	33.21 *c*	17.38 *ab*	230.34 *a*	42.37 *c*	28.25 *b*	30.84 *b*	1.77 *b*	0.22 *b*	0.40 *a*
	LSD (5%)	5.84	130.5	13.16	72.8	64.3	26.06	38.13	1.40	0.19	0.27
Siufaga	Grass	7.03 *b*	71.71 *b*	10.55 *b*	81.55 *b*	39.37 *b*	40.07 *b*	40.47 *b*	1.36 *b*	0.11 *b*	0.30 *b*
	Mucuna	35.92 *a*	700.49 *a*	122.14 *a*	506.51 *a*	370.00 *a*	140.10 *a*	60.44 *a*	5.07 *a*	0.94 *a*	1.19 *a*
	Erythrina	4.49 *c*	155.80 *b*	15.27 *b*	112.70 *b*	89.35 *b*	14.82 *c*	1.58 *c*	0.31 *b*	0.05 *b*	0.18 *b*
	LSD (5%)	11.55	241.0	41.10	169.9	106.4	54.82	26.80	1.79	0.22	0.4
LSD (5%) for between site comparison	Grass	3.32	32.70	5.89	45.09	17.25	19.16	21.29	0.85	0.06	0.17
	Mucuna	11.03	245.4	34.16	159.1	107.5	46.14	50.13	2.08	0.27	0.36
	Erythrina	2.04	66.8	6.57	46.14	34.66	8.50	0.62	0.22	0.03	0.08
	Biochar	7.35	25.77	16.69	86.9	31.90	20.79	34.26	0.05	0.24	0.46

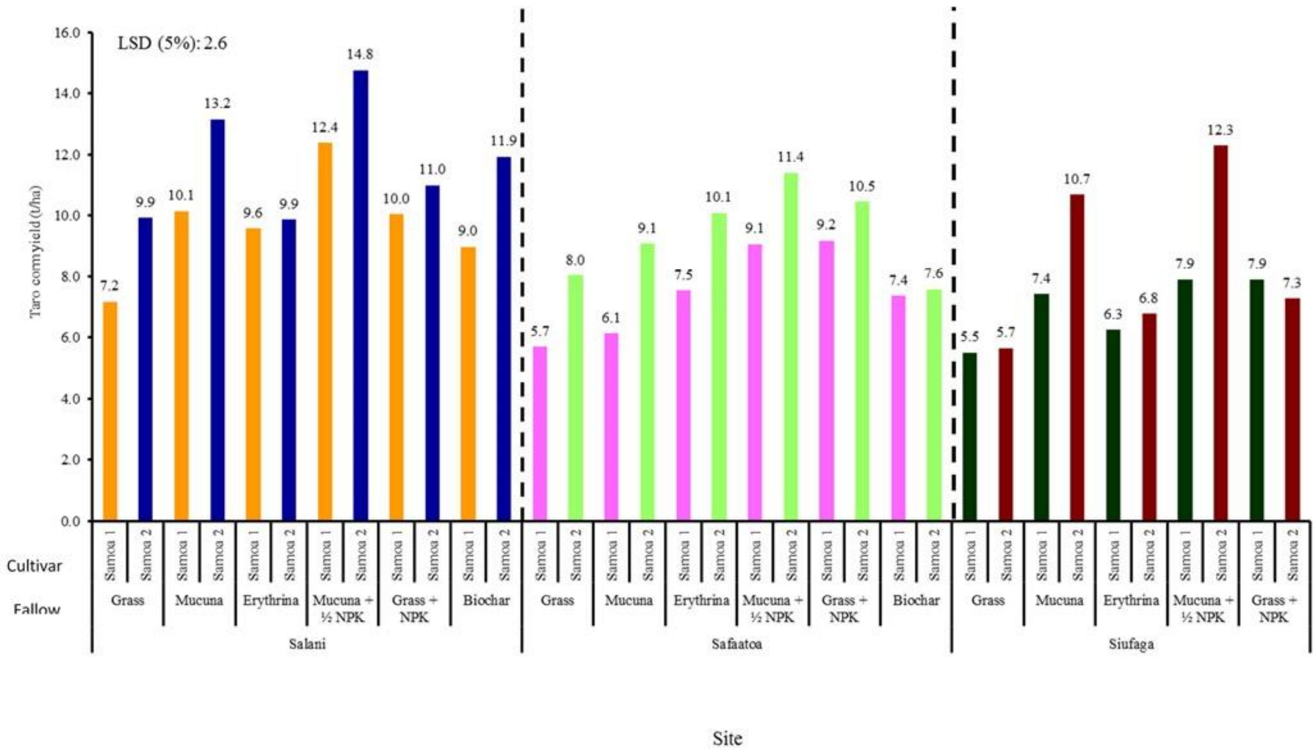

Figure 1. Corm yield of the two cultivars of taro from the three sites