Nutrient Use Efficiencies of Taro Cultivars Genetically Improved for Leaf Blight Resistance

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Abstract: Two blight resistant taro cultivars, *taro uli* and *taro mumu* were planted and harvested for biomass measurements on a monthly basis for a total of eight months through destructive sampling. It is worthy to note that *taro uli* plants absorbed 17% less N, 26% less P and 20% less K than those of *taro mumu*. Although *taro mumu* resulted in higher total plant (21.4%) and corm dry matter (10.4%) productions, cultivar *taro uli* had a higher nutrient use efficiency over *taro mumu*. Results show that *taro mumu* had a higher nutrient use efficiency over cultivar *taro uli*. Based on nutrient use efficiency of the cultivars, *taro uli* is recommended for marginal to rich soils while *taro mumu* for rich soils.

Keywords: Dry Matter Accumulation, Nutrient Uptake, Nutrient Use Efficiency, Destructive Sampling.

Introduction: Tropical Root Crops are a major source of dietary energy for majority of the Pacific Island populations. Among the food crops in Oceania region, the adulation and prestige attached to taro is equalled only by yam in certain localities (Tuivavalagi et al., 2004). Variations in mineral composition among the accessions of taro is probably due to differences in the genetic potential of each accession to obtain nutrients from the soil since different taro genotypes have different nutrient-use efficiencies (Guchhait et al., 2008; Goenaga and Chardon, 1995). As was found in the same study, regarding mineral content, high levels of variability in South East Asia and Oceania taro germplasm were also found with regards to **chemical composition** for minerals but also for lipids, proteins, amylose, glucose, fructose and saccharose (Guchhait et al., 2008; Goenaga and Chardon, 2008).
Availability of N, P, K and S fertilizers increase yield as well as nutritional quality of root and tuber crops (Wang et al., 2008).

In most studies on food crops in the Pacific, nutrient use efficiencies receive little attention, particularly due to the tedious and difficult nature of the quantification process (Lebot et al., 2004). This has led to a scarcity of basic information regarding dry matter accumulation and nutrient uptake for the taro crop, particularly under intensive cropping systems which are aimed at satisfying the crop demand of a growing population and supplying corms for export markets.

An essential step to increase the efficiency of fertilizers in order to improve yields is an understanding of nutrient uptake and allocation within the taro plant during the growing season. These data are essential for the development of technological packages, especially involving nutrient inputs, growth simulation models, and decision support system (Goenaga and Chardon, 2008). This information is also critical for the establishment of taro breeding programs aimed at raising the yield potential and nutritive value of taro.
Therefore, it is imperative to ascertain the nutrient uptake data which reflects on the nutritional value data for the new cultivars in order to realize their full economic potential.

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Methodology: Suckers of two improved taro cultivars, *taro uli* and *taro mumu*, were planted in a factorial arrangement, using randomised complete block design with five replications. Each replication consisted of plots randomly assigned to the two cultivars which were to accommodate eight randomly assigned monthly biomass harvests, sampled for dry matter accumulation and nutrient uptake at different stages of plant growth. There were six data plants of each variety from each block for each of the eight harvests totalling 240 plants for each cultivar (480 plants for the whole experiment). The cultivars and harvest periods were completely randomized within a block. Six taro plants of each cultivar from a block were harvested at 30, 60, 90, 120, 150, 180, 210, and 240 days after planting (DAP), to ascertain the dry matter measurements and total chemical analysis of individual plant parts. Plants in the sub-plots were harvested, washed and separated into petioles, corms, roots and sucker components. Samples of the various plant parts were oven dried to a constant weight at 65°C for dry matter determination. The dried samples were ground to pass through a 1.0-mesh screen and analysed for total N, P, K, Ca, Mg, Fe, Mn, Cu and Zn. Nitrogen was determined by the micro-Kjeldahl procedure
(Asher et al., 2002), P by molybdovanadophosphoric acid (IBSNAT, 1987), and K, Ca, Mg, Zn, Fe, Mn, and Cu by atomic absorption spectrophotometry (Chapman and Pratt, 1961; Prasad and Spiers, 1978).

Nutrient uptake and accumulation were calculated as the product of dry matter content and tissue nutrient concentrations for the various plant parts at various stages of growth over the entire growth cycle of the crop. The mean values from the six data plants, for each nutritional index and the number of plants per hectare were used to extrapolate nutrient uptake on a hectare basis. The nutrient use efficiency was calculated as the kg of corm dry matter produced per kg of nutrient taken up (Goenaga and Chardon, 2008).

All the data collected were subjected to two-way analysis of variance for differences between cultivars. Best-fit models were determined using polynomial regression procedures of the Genstat Statistical Software package (VSNI, 2011). Only coefficients significant at $P < 0.05$ were retained in the model.

Results: The models for increase dry weights of various plant organs of the two taro cultivars as influenced by age is given in Appendix Table 1. The mean total dry matter yield showed cultivar *taro mumu* had 21.4% higher gain than cultivar *taro uli* across the 8 monthly harvest period. The first 90 days after planting (DAP) were characterized by low rates of growth by both the cultivars, however, statistically significant with cultivar *taro mumu* accumulating higher dry matter yield. During this period, leaves and petioles accounted for 49% of the total dry matter produced in each cultivar. Following 210 DAP, the dry matter content in the leaves and petioles declined to less than 19% of the total dry matter, but it increased significantly in corms and suckers. During the first 90 DAP, roots of cultivars *taro uli* and *taro mumu* represented about 11% and 17% of the total dry matter content, for *taro mumu*. Cultivar *taro mumu* accumulated significantly higher root dry matter than *taro uli* throughout the experimental period. It is noteworthy that, between 150 and 240 DAP, the suckers were a significant sink of dry matter in the taro plant. During this period, these organs accounted for

19% of the total plant dry matter in *taro uli* and 12% in *taro mumu*. Maximum significant dry matter accumulation in the corms of both cultivars was recorded between 210 and 240 DAP, accounting for about 42% of the total plant dry matter.

The models defining the uptake of various macro and micro nutrients by the two cultivars is given in Appendix Table 2. Two way analysis of variance revealed significantly higher uptake of N (25%), P (33.2%), K (27%), Mg (33.7%), Mn (24.37%) and Zn (44.6%) by cultivar *taro mumu* (see Appendix Table 4). In general, the nutrient uptake was very similar between cultivars during the first 150 DAP; thereafter, the quantity of all the nutrients taken up by plants of cultivar *taro uli* was lower than that of cultivar *taro mumu*. The only exception was for Fe uptake where uptake by cultivar *taro uli* was higher than cultivar *taro mumu*, however, this was not significant. The linear models defining the nutrient use efficiencies of the two cultivars are given in see Appendix Table 3. There were significant differences in the total and corm dry matter productions as well as nutrient uptake between the cultivars (Table 4). Cultivar *taro uli* had a higher nutrient use efficiency (kg of edible dry matter produced per kg of nutrient taken up), for N, P, K, Mg, Mn and Cu over cultivar t*aro mumu*. However, for Ca, Fe and Zn, cultivar *taro mumu* had a higher nutrient use efficiency over cultivar *taro uli*. The efficiencies were determined by comparing the slopes of the linear models, which showed the gain of edible corm dry matter for every kg of nutrient uptake, see Appendix Table 3.

Taro exhibits continuous partitioning (a balance between vegetative growth and storage organ growth is maintained throughout the growing) with an almost linear increase in fresh and dry weights (Onsorio et al., 2003). The dynamics of dry matter accumulation, nutrient uptake and partitioning by two taro cultivars with under natural open field conditions showed similar patterns from a research carried out in Isabella, Puerto Rico (Goenaga and Chardon, 1995).

The findings of this study showed that the dry matter accumulation by various plant organs followed analogous sigmoid patterns over the crop life cycle as reported by other authors (Goenaga and Chardon, 2008). Towards senescence, the suckers were the principal sink of dry matter for both the cultivars. This result is of particular importance because, when taro is grown under upland conditions, cormels of suckers seldom reach a marketable size; and they may compete for assimilates with the marketable main corm. This finding may influence such decisions as to remove the competing suckers at later stages of crop growth (Guchhait et al., 2008).

The comparatively higher nutrient uptake of cultivar *taro mumu* can be ascribed to the genotypic variations as reported by various other researchers who worked with taro (Goenaga and Chardon, 2008; Saud et al., 2013). Other studies on the N, P and K content of different plant parts at various growth stages revealed that the nutrient content changes with increase in age of the crop. The N and K contents in the foliage of taro were reported to be at its highest after 150 DAP; thereafter, decreased with maturity. The N content of root, tuber and pseudo-stem decreased towards maturity of the crop (Goenaga and Chardon, 1995). This was in agreement with the findings of this study with days after planting highly significant across all the nutrients analysed.

Both cultivars exhibited higher levels of K uptake relative to N. This suggests that, as with most root crops, taro has a high requirement for K relative to N. Analogous findings were reported with the total plant as well as corm being characterised by high concentrations of K (Mergedus et al., 2014). Poassium application resulted in greater leaf area and leaf area duration and exerted a profound influence in diverting greater proportion of dry matter into corms than N and increased the dry matter accumulation in corms corm size, and yield. The increase in corm yield due to K was attributed partly to its effect in bringing about slightly earlier corm initiation and partly to an increase in bulking rate (John, 2011).

The variations in the leaf tissue nutrient concentrations can be attributed to genetic differences between the cultivars (Mwenye, 2011). Higher plant vigour and sucker production was observed by cultivar *taro mumu* relative to cultivar *taro uli* (Anand, 2016). Among the different plant portions, leaf was found to be the the richest in N (4-5%). Parallel findings were reported by other researchers (Wills et al., 2003; John, 2011). This is of high nutritional significance, since leaves are consumed as fresh vegetable in the Pacific island communities.

Furthermore, the nutrient use efficiencies, computed as the weight of edible dry matter produced for every kg of nutrient taken up, revealed that though cultivar *taro mumu* had higher nutrient uptake, it required greater quantities of N, P, K, Mg, Mn and Cu to produce one kg of dry matter as compared to cultivar *taro uli*. Conversely, Ca, Fe and Zn were required in relatively higher amounts by *taro uli* as opposed to cultivar *taro mumu*, to produce 1 unit of corm dry matter.

In another separate field trial, the effect of the taro genotype was significant for more than half of the analysed minerals (i.e., Mg, Ca, Zn, Fe, Mn) (Mergedus et al., 2014). Efficiency ratios can be influenced by the duration of the crop, fertilisation, amount of solar radiation and drought (Goenaga and Chardon, 1995). Therefore, comparison of ratios among species or cultivars and across environments or management packages should be conducted with caution (John, 2011)..

Conclusions: There has been limited number of experiments in the Pacific characterising the inter-relationship between growth, development and nutrient uptake of the taro crop. However, as the demand for taro increases in the local, processing and export markets, the required volume will only be met through extensive plantings using modern management packages.

Implementation of such technological packages will require readdressing the current cultural and management practices and basic research to achieve higher yields.

The results of this study exhibited the inherent cultivar differences in relation to patterns of dry matter accumulation in various components of the taro plant.

The results of this study also revealed that both of the locally bred taro cultivars from Samoa are capable of absorbing a wide range of minerals with relevance to human dietary allowances and health. A complete information package on the nutritional composition of local taro germplasm would help to guide policy makers, nutritionist and researchers in incorporating the crop cultivars into the various diversification programs.

This investigation revealed that overall cultivar *taro uli* had had a relatively better nutrient use efficiency than cultivar *taro mumu*. On the basis of this finding, *taro uli* is better adapted for marginal to rich soils while *taro mumu* for moderate to rich soils. Results from this investigation can be valuable for breeding programs dealing improvements in taro nutrient use efficiency as well as nutritional composition.

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Table 1. Polynomial models defining dry weights of plant organs of the two taro cultivars as influenced by age

Plant organ	Cultivar	Model defining dry matter gains over eight month period	R^2 Values
Whole plant	*Taro uli*	$Y = 0.19x^2 - 12.06x + 389.25$	0.91
	Taro mumu	$Y = 0.07x^2 - 4.75x + 204.11$	0.95
Leaves	*Taro uli*	$Y = 0.03x^2 + 0.18x + 17.28$	0.94
	Taro mumu	$Y = 0.01x^2 + 0.94x + 9.45$	0.92
Petioles	*Taro uli*	$Y = 0.04x^2 - 4.12x + 104.89$	0.93
	Taro mumu	$Y = 0.02x^2 - 3.04x + 82.97$	0.91
Roots	*Taro uli*	$Y = 0.01x^2 - 0.13x + 20.88$	0.92
	Taro mumu	$Y = 0.01x^2 + 0.52x + 10.81$	0.94
Corms	*Taro uli*	$Y = 0.03^2 + 0.44x + 22.13$	0.93
	Taro mumu	$Y = 0.04x^2 – 5.31x + 98.65$	0.94
Suckers	*Taro uli*	$Y = -0.01x^2 + 6.58x - 522.74$	0.97
	Taro mumu	$Y = -0.01x^2 + 5.34x - 488.53$	0.93

Table 2. Models defining the nutrient accrual by the two taro cultivars as influenced by age

Plant Nutrient	Cultivar	Model defining nutrient accrual over eight month period	R^2 Values
Nitrogen	*Taro uli*	$Y = 0.01x^2 - 1.07x + 39.82$	0.91
	Taro mumu	$Y = 1.434x - 28.72$	0.92
Phosphorus	*Taro uli*	$Y = 0.02x^2 - 0.42x + 11.61$	0.92
	Taro mumu	$Y = 0.24x - 8.42$	0.94
Potassium	*Taro uli*	$Y = 0.04x^2 - 4.05x + 97.12$	0.93
	Taro mumu	$Y = 0.02x^2 – 0.98x + 41.33$	0.94
Calcium	*Taro uli*	$Y = - 0.07x^2 + 3.65x - 91.71$	0.84
	Taro mumu	$Y = - 0.11x^2 + 3.79x - 80.47$	0.86
Magnesium	*Taro uli*	$Y = 0.04x^2 - 0.18x + 3.88$	0.92
	Taro mumu	$Y = 0.03x^2 - 0.06x + 1.55$	0.94
Iron	*Taro uli*	$Y = - 0.07x^2 + 0.19x$	0.83
	Taro mumu	$Y = 0.06x^2 + 0.15x - 2.08$	0.88
Manganese	*Taro uli*	$Y = - 0.04x + 0.41$	0.94
	Taro mumu	$Y = 0.02 + 0.44$	0.96
Copper	*Taro uli*	$Y = 0.05x - 0.07$	0.77
	Taro mumu	$Y = 0.04x - 0.07$	0.84
Zinc	*Taro uli*	$Y = - 0.06x + 0.21$	0.91
	Taro mumu	$Y = 0.02x - 0.09$	0.95

Table 3. Linear models defining the use efficiencies for the essential nutrient elements by the two taro cultivars

Plant Nutrient	Cultivar	Linear model defining nutrient use efficiencies for various nutrients	R^2 Values
Nitrogen	*Taro uli*	Y = 4.52x - 105.63	0.84
	Taro mumu	Y = 3.85x - 93.22	0.81
Phosphorus	*Taro uli*	Y = 17.66x - 10.37	0.94
	Taro mumu	Y = 14.73x + 6.81	0.93
Potassium	*Taro uli*	Y = 2.73x - 57.44	0.95
	Taro mumu	Y = 2.26x - 61.7	0.82
Calcium	*Taro uli*	Y = 3.51x + 79.67	0.86
	Taro mumu	Y = 4.07x + 76.93	0.91
Magnesium	*Taro uli*	Y = 27.29x - 41.36	0.87
	Taro mumu	Y = 22.433x - 57.17	0.94
Iron	*Taro uli*	Y = 28.97x + 65.86	0.89
	Taro mumu	Y = 42.39x + 73.22	0.87
Manganese	*Taro uli*	Y = 685.63x - 37.51	0.94
	Taro mumu	Y= 615.62x - 29.49	0.93
Copper	*Taro uli*	Y = 7652.40x - 61.46	0.84
	Taro mumu	Y = 8074.30x - 77.04	0.79
Zinc	*Taro uli*	Y = 1527.84x - 32.45	0.90
	Taro mumu	Y = 1214.73x - 56.81	0.91

Table 4. Mean dry matter (TDM) yield (kg/ha) and plant uptake (kg/ha) of various nutrients by the two cultivars across the 8 monthly biomass harvests.

Cultivar				Mean (kg/ha)					
	TDM*	N**	P***	K***	Ca	Mg***	Fe	Mn	Cu	Zn***
taro uli	672	72.4	12.1	93.6	44.3	9.2	5.2	0.39	0.04	0.14
taro mumu	792	92.9	19.6	138.4	53.4	12.2	4.9	0.33	0.03	0.23
LSD (5%)	97.3	11.02	2.05	24.36	11.12	1.62	1.5	0.09	0.01	0.03

*, **, *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively.