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Dry Matter Accumulation, Nutrient Uptake and Nutrient Use Efficiency of Two Improved Cultivars of Taro (Colocasia Esculenta) Under Screen House Conditions in Samoa

Abstract

Taro *(Colocasia esculenta* (L.) Schott) is a staple crop of many of the South Pacific nations with an ever increasing export demand. In recent years, yields of taro have increased dramatically through breeding and selection. However, selection of improved lines is often based entirely on final yield. There are many physiological pathways by which increased potential yield may be achieved. Factors such as the accumulation of dry matter and nutrient use efficiency, merit investigation.

Two improved (blight resistant) taro cultivars were planted and harvested for biomass measurements on a monthly basis for a total of eight months (30-240 days after planting) through destructive sampling. At each harvest, plants were separated into various plant parts and their dry matter accumulation and nutrient content were determined. Since there were no significant differences in the total and corm dry matter productions between the cultivars, it can rationally be said that cultivar Samoa 1 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 Samoa 2. However, for Ca, Fe and Zn, it is logical to consider that cultivar Samoa 2 had a higher nutrient use efficiency over cultivar Samoa 1.

Keywords: Dry matter accumulation, nutrient uptake, nutrient use efficiency, destructive sampling

Introduction

Root and tuber crops are the major sources of dietary energy for many people in the Pacific island countries. In the Pacific Islands, taro has always been richly woven into the fabric of life. Taro is postulated to have originated in southern or south-east Asia, and to have been dispersed to Oceania through the Island of New Guinea very many centuries ago. The crop has evolved with the cultures of the people of the Asia/Pacific region. Not surprisingly, it has acquired considerable socio-cultural importance for the people. Among the food crops in Oceania region, the adulation and prestige attached to taro is equalled only by yam in certain localities.

In most studies with food crops, biomass production and nutrient uptake receive little attention, particularly due to the tedious and difficult nature of the quantification process. 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 fertilisers 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

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simulation models, and decision support system. This information is also critical for the establishment of taro breeding programs aimed at raising the yield potential of taro.

Research objective

The objective of this research is to investigate the dry matter accumulation and nutrient use efficiency for two improved taro cultivars grown under semi-controlled screen house environment, through regular temporal destructive sampling.

Materials and methods

Description of the trial

This experiment was conducted to investigate the nutrient uptake of the two improved (blight resistant) taro cultivars grown for the fallow experiment, *Samoa 1 and Samoa 2*. The experiment was executed under the semi controlled environment of a screen house, with the taro being grown in pots. The soil used was a well-drained Inceptisol (Oxic Humitropept, clayey-skeletal oxidic isohyperthermic) with pH = 6.0; organic carbon = 3.2%; and exchangeable bases = 10.3 cmol(+)/kg of soil. The soil was air dried and sieved through a 1 cm mesh. The potting bags were filled with 10 kg of soil each.

Nutrient supplementation and incubation

The entire package of macro and macronutrient elements, based on the soil pH, was included for nutrient supplementation to each pot, carried out at recommended levels by Asher *et al.* (2002) (Table 1). An incubation time of two weeks was allowed before the planting of the two taro varieties.

Experimental design, layout and size

Suckers of two improved taro cultivars, *Samoa 1* and *Samoa 2*, were planted in pots and laid out in a split-plot arrangement, using randomised complete block design with five replications. Each replication consisted of two main plots as the cultivars which were split to accommodate eight 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 (each sub-plot) for each of the eight harvests totaling to 240 plants for each cultivar (480 plants for the whole experiment). The cultivars and harvests were completely randomised within a block.

Data collection

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^{o}C for dry matter determination. The dried samples were ground to pass through a 1.0-mesh screen and analysed for N, P, K, Ca, Mg, Fe, Mn, Cu and Zn. The third most upper leaf laminar was also analysed for these elements at 30, 60, 90, 120, 150, 180, 210, and 240 days after planting (DAP). Nitrogen was determined by the micro-Kjeldahl procedure (IBSNAT, 1987), P by molybdovanadophosphoric acid (IBSNAT, 1987), and K, Ca, Mg, Zn, Fe, Mn, and Cu by atomic absorption spectrophtometry (Chapman and Prat, 1961; Prasad and Speirs, 1978). Nutrient content were calculated as the product of dry matter content and tissue nutrient concentration.

Statistical analysis

All the data collected were subjected to analysis of variance using ANOVA for split plot treatment arrangement laid out in a randomised complete block design structure. Best-fit curves were determined using polynomial regression procedures of the Genstat Statistical Software package (VSN International Ltd., 2016). Only coefficients significant at $P < 0.05$ were retained in the model.

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Table 1 Typical rates of nutrient supplementation for soils with a pH of 6.0

Element	Rates of application of element (kg/ha)	Compound	Molecular weight	Weight conversion factor - element to salt	Rates of application of salt (kg/ha)	Concentration of stock solution (g salt/L)
N	100	NH_4NO_3	80.04	2.86	286.00	104.02
P	60	$NaH_2PO_4.2H_2O$	178.00	5.75	346.00	125.60
K	80	KCl	78.56	2.01	161.00	58.60
Ca	35	$CaCl_2$	112.00	2.79	98.00	35.70
Mg	30	$MgCl_2.6H_2O$	203.30	8.35	250.00	91.00
S	25	Na_2SO_4	142.00	4.42	111.00	40.40
Fe	5	Sequestrene 138	-	16.70	100.00	36.40
B	2	H_3BO_3	61.84	5.72	11.40	4.14
Zn	4	$ZnCl_2$	136.30	2.08	8.34	3.02
Mn	5	$MnCl_2.4H_2O$	179.90	3.27	16.35	5.96
Cu	3	$CuCl_2.2H_2O$	170.50	2.68	8.04	2.92
Mo	0.4	$[NH_4]_6Mo_7O_{24}.H_2O$	1236.00	12.88	5.15	1.87
Co	0.1	$CoCl_2.6H_2O$	237.95	4.04	0.404	0.15
Ni	0.1	$NiCl_2.6H_2O$	237.72	4.05	0.405	0.15

(Source: Asher *et al.*, 2002)

Results and Discussion

Dry matter accumulation by various plant organs

The accumulation of dry matter by various plant organs of the two cultivars is illustrated in Figure 1a-f. Total dry matter did not differ significantly between cultivars throughout the experimental period (Table 2). The first 90 days after planting (DAP) were characterised by low rates of total dry matter production by both the cultivars (Figure 1a). During this period, leaves and petioles accounted for 58%

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of the total dry matter produced in each cultivar (Figure 1a-c). Following 210 DAP, the dry matter content in the leaves and petioles declined to less than 25% of the total dry matter, but it increased significantly in corms and suckers (Figure 1e and f). During the first 90 DAP, roots of cultivars Samoa 1 and Samoa 2 represented about 13% and 18% of the total dry matter content, respectively. Following 180 DAP, the dry matter content in the roots was never higher than 8% for Samoa 1 and 12% for Samoa 2. Cultivar Samoa 2 accumulated significantly higher root dry matter than Samoa 1 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 22% of the total plant dry matter in Samoa 1 and 13% in Samoa 2. These results are 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. Maximum significant dry matter accumulation in the corms of both the cultivars was recorded between 210 and 240 DAP, accounting for about 46% of the total plant dry matter.

Nutrient uptake of the two taro cultivars as influenced by plant age

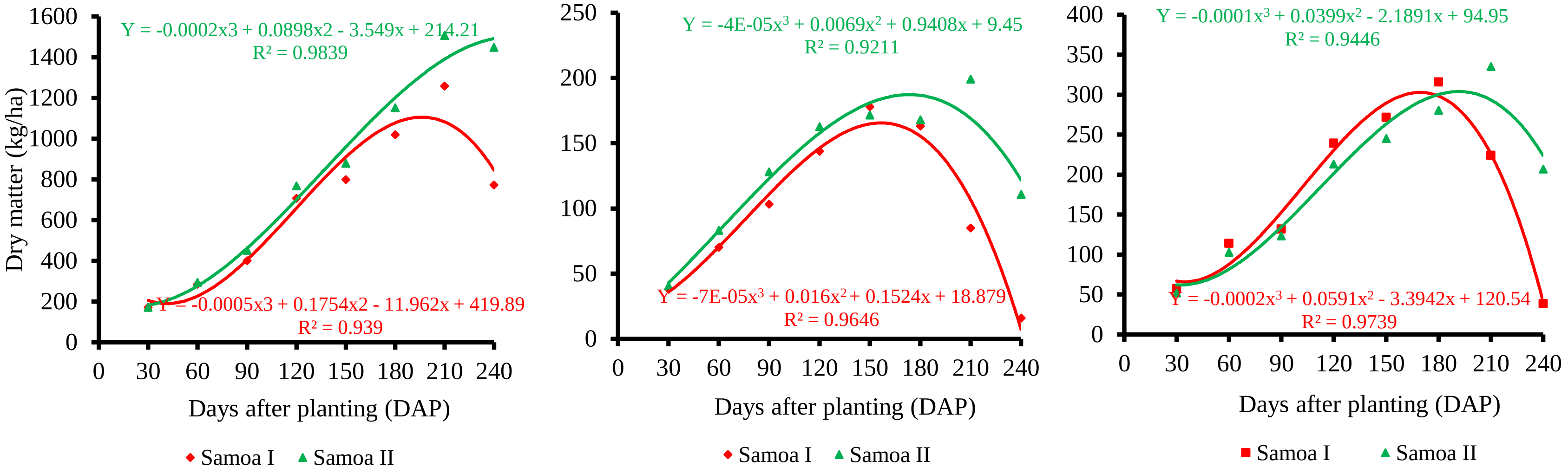
Except for P, Mg and Zn, there was no statistical significance between the cultivars for the quantity of nutrients taken up by plants (Table 2). In general, the nutrient uptake was very similar between cultivars during the first 150 DAP; thereafter, the quantity of all the nutrients taken up by plants of cultivar Samoa 1 was lower than that of cultivar Samoa 2, however, only significant for P, Mg and Zn. The only exception was for Fe uptake where uptake by cultivar Samoa 1 was higher than culticar Samoa 2, however, this was not significant (Figure 2a-e and Figure 3 a-d). Maximum uptake values for the two cultivars are given in Table 3.

Maximum levels of nutrient uptake by the two cultivars (kg/ha)

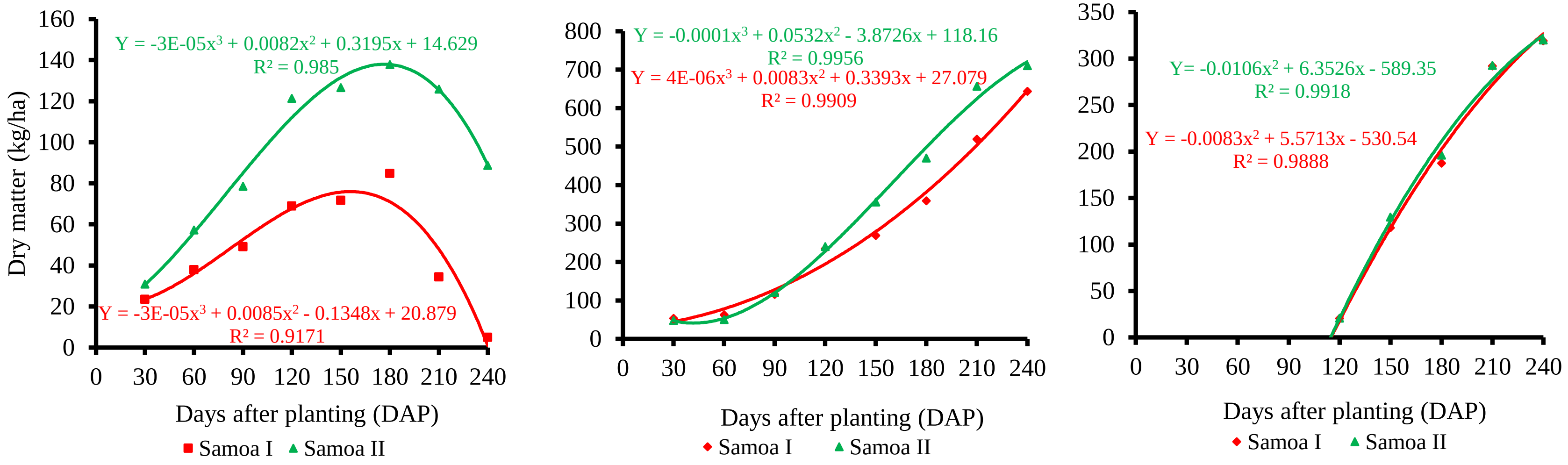
It is noteworthy that cultivar Samoa 1 plants absorbed 20% less K and 17% less N than those of cultivar Samoa 2 with the uptake uniformly distributed over the entire life cycle of the crop. These results also confirms that, as with most root crops, taro has a high requirement for K relative to N (Goenaga and Chardon, 1995; Norman *et al.*, 1994). Mergedus *et al.* (2014) also reported analogous findings with the corm being characterised by high concentrations of K.

The third uppermost leaf laminar is often used to determine the nutritional status of aroid crops including taro (Goenaga and Chardon, 1995). In general, the concentrations of all the nutrients except Fe in the leaf laminar of cultivar Samoa 1 plants had greater concentrations than cultivar Samoa 2 plants.

Since there were no significant differences in the total and corm dry matter productions between the cultivars (Table 2), it can rationally be said that cultivar Samoa 1 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 Samoa 2. However, for Ca, Fe and Zn, it is logical to consider that cultivar Samoa 2 had a higher nutrient use efficiency over cultivar Samoa 1 (Figure 4 and Figure 5). Mergedus *et al.* (2014) concluded that the effect of the taro genotype was significant for more than half of the analysed minerals (i.e., Mg, Ca, Zn, Fe, Mn).



(a) Total (b) Leaves (c) Petiole



(d) Roots (e) Corms (f) Suckers

Figure 1 Dry weights of plant organs of the two taro cultivars as influenced by age

Table 2 Analysis of variance for effects of cultivar and days after planting on total dry weight and plant uptake of various nutrients

Source	df	Mean Squares									
		Total dry matter	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Block	4	13024	634.9	29.54	283	1274.6	13.62	8.70	0.023	0.0014790	0.006684
Cultivar (CV)	1	423681	7756.7	507.49*	33206	1342.4	297.99*	0.68	0.190	0.0011110	0.148525**
Error (a)	4	69857	1823.3	44.33	4351	482.7	38.86	11.31	0.046	0.0005035	0.007752
Days after planting (DAP)	7	1816280***	20029.5***	1415.54***	68008***	31116.7***	618.67***	186.70***	1.000***	0.0079679***	0.210027***
CV x DAP	7	122785	1634.0	183.46***	5860	1017.3	105.35***	5.43	0.061	0.0001913	0.025468***
Error (b)	56	55551	816.5	21.13	2868	628.1	12.92	11.29	0.037	0.0005920	0.004510

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

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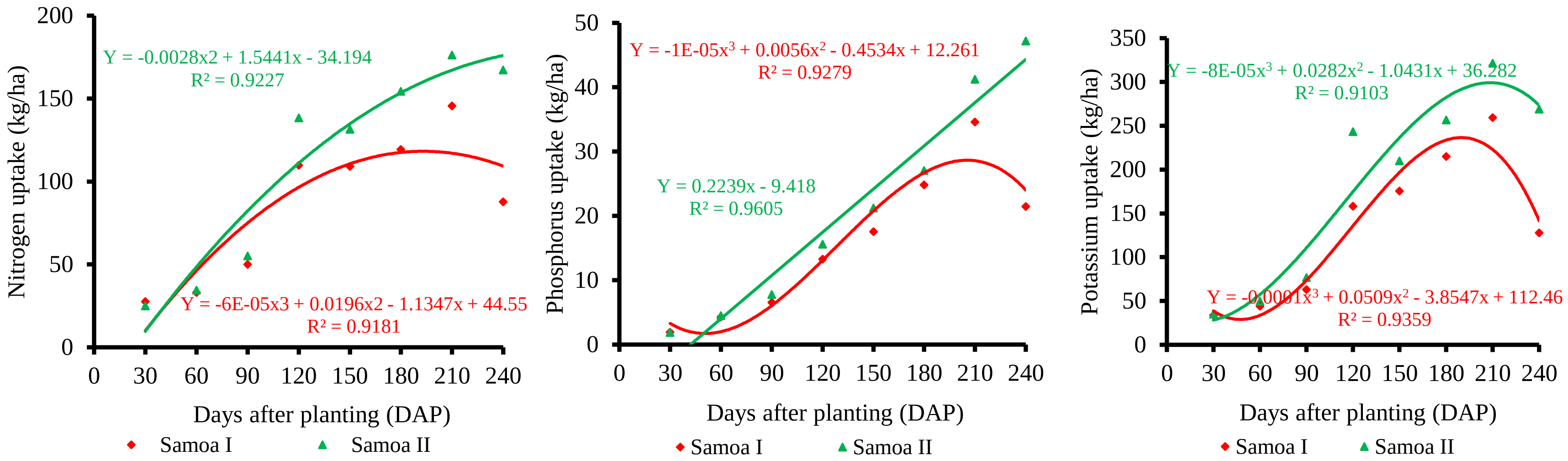
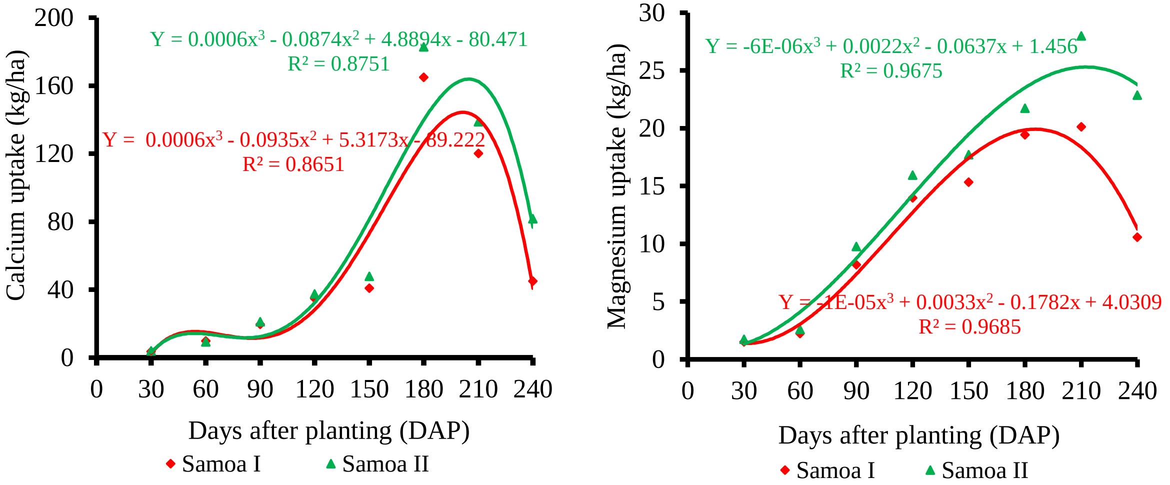
Table 3 Maximum levels of nutrient uptake by the two cultivars (kg/ha)

Macronutrient	Samoa I	Samoa II
N	146	176
P	35	41
K	259	321
Ca	165	183
Mg	20	28
Micronutrient		
Fe	21	10
Mn	0.9	1.1
Cu	0.07	0.08
Zn	0.39	0.54



(a) Nitrogen (b) Phosphorus (c) Potassium



(d) Calcium (e) Magnesium

Figure 2 Macronutrient contents of the two taro cultivars as influenced by plant age

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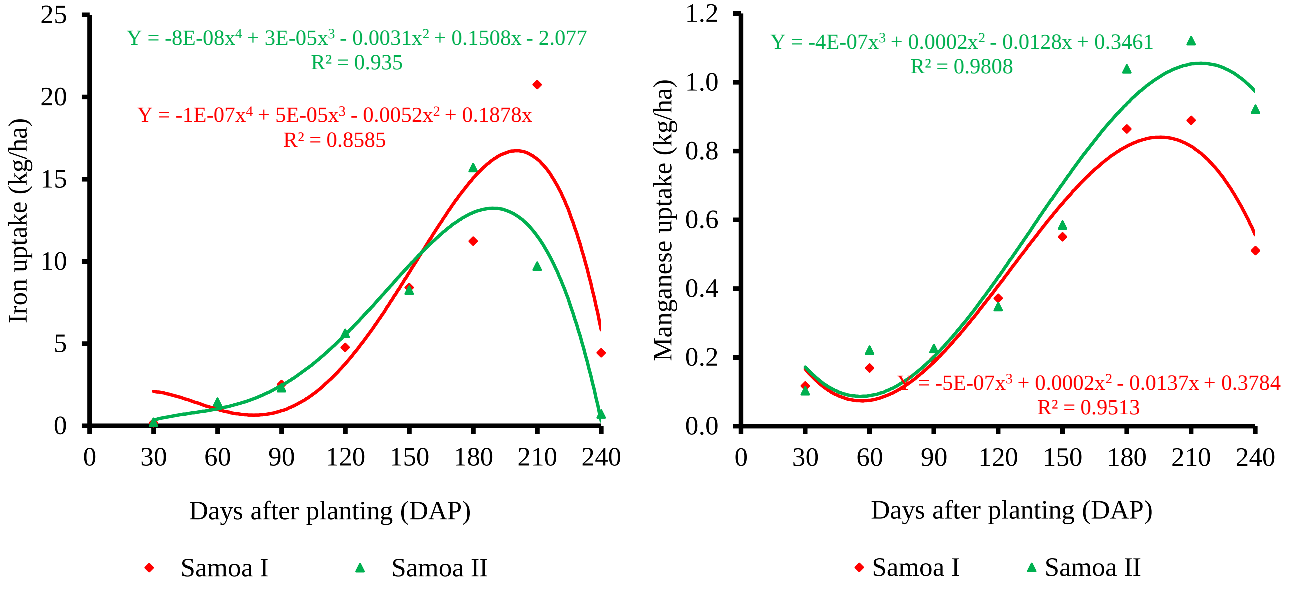
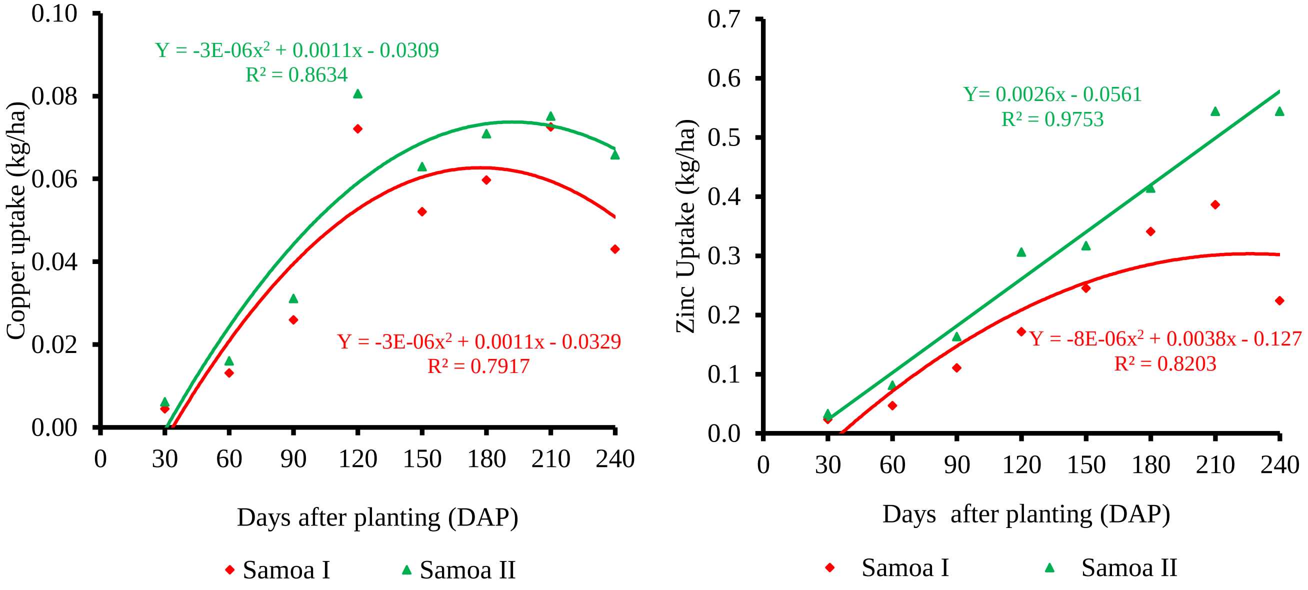


(a) Iron

(b) Manganese



(c) Copper

(d) Zinc

Figure 3 Micronutrient contents of the two taro cultivars as influenced by plant age

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Nutrient concentration of the two taro cultivars

Table 4 Percent nutrient concentration in the lamina of the third uppermost leaf of the two taro cultivars at various stages of growth.

Days after planting	Cultivar	Nutrient Content (%)								
		N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
30	Samoa 1	4.73	0.33	3.85	0.97	0.18	0.104	0.068	0.003	0.014
	Samoa 2	4.87	0.34	2.87	0.78	0.30	0.120	0.060	0.004	0.019
60	Samoa 1	4.21	0.44	3.33	1.82	0.16	0.425	0.059	0.005	0.017
	Samoa 2	4.39	0.46	3.11	1.54	0.18	0.489	0.075	0.005	0.028
90	Samoa 1	3.89	0.41	2.93	2.30	0.37	0.625	0.049	0.006	0.028
	Samoa 2	4.01	0.44	2.89	2.21	0.45	0.513	0.050	0.007	0.036
120	Samoa 1	4.37	0.41	3.75	2.23	0.37	0.675	0.053	0.010	0.024
	Samoa 2	4.53	0.43	3.71	1.76	0.37	0.733	0.045	0.011	0.040
150	Samoa 1	3.94	0.41	4.01	1.42	0.35	1.052	0.069	0.007	0.031
	Samoa 2	4.29	0.39	4.00	1.17	0.29	0.940	0.067	0.007	0.036
180	Samoa 1	2.94	0.39	3.78	12.11	0.31	1.103	0.085	0.006	0.033
	Samoa 2	3.43	0.38	3.63	10.82	0.31	1.364	0.090	0.006	0.036
210	Samoa 1	3.14	0.47	3.35	2.40	0.27	1.649	0.071	0.006	0.031
	Samoa 2	3.18	0.40	3.35	1.97	0.29	0.645	0.074	0.005	0.036
240	Samoa 1	4.18	0.56	3.34	1.95	0.36	0.575	0.066	0.006	0.029
	Samoa 2	3.41	0.48	2.91	2.41	0.34	0.050	0.064	0.005	0.038

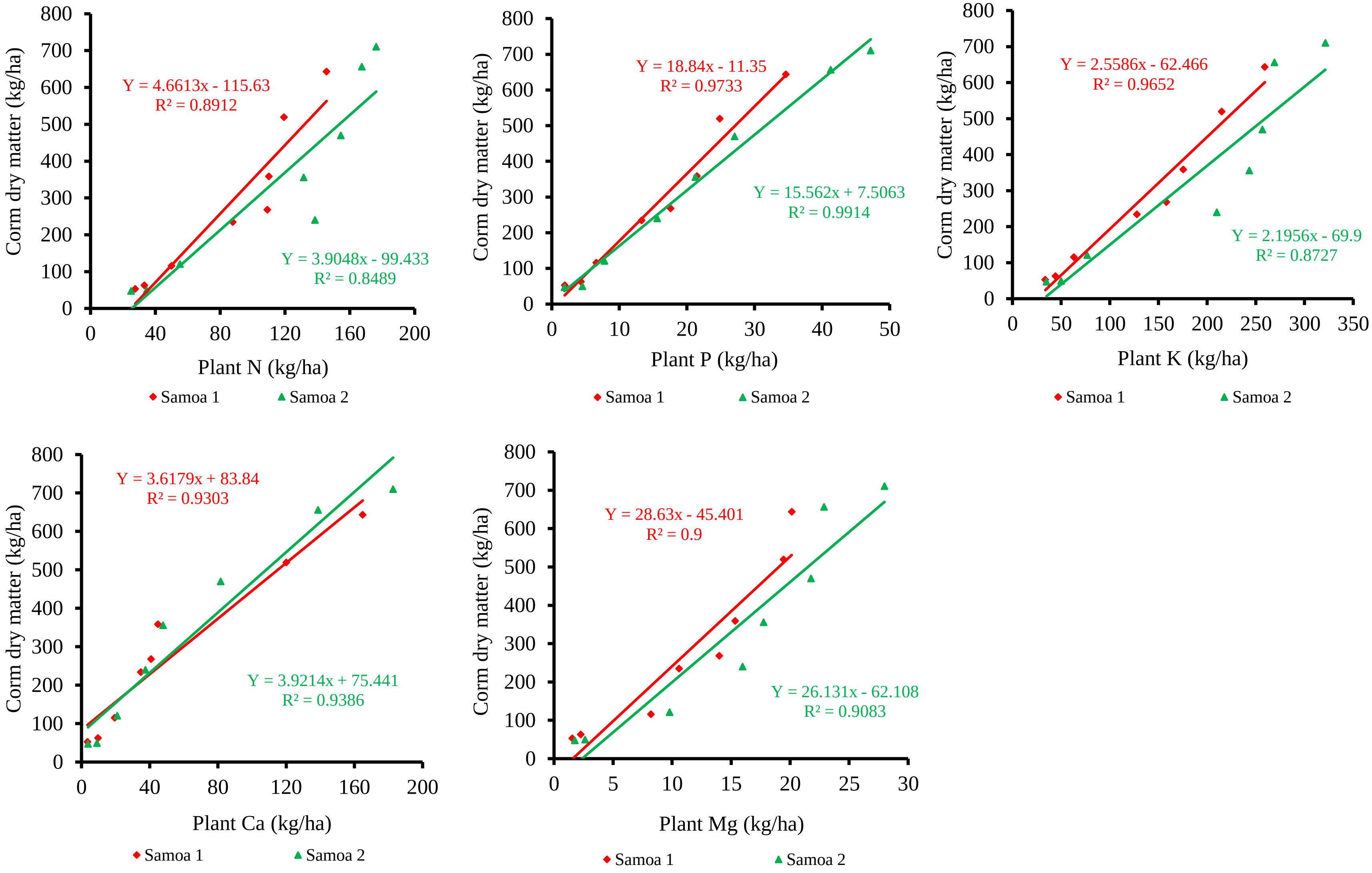

Figure 4 Relationship between corm dry matter yield and macronutrient contents of the two cultivars

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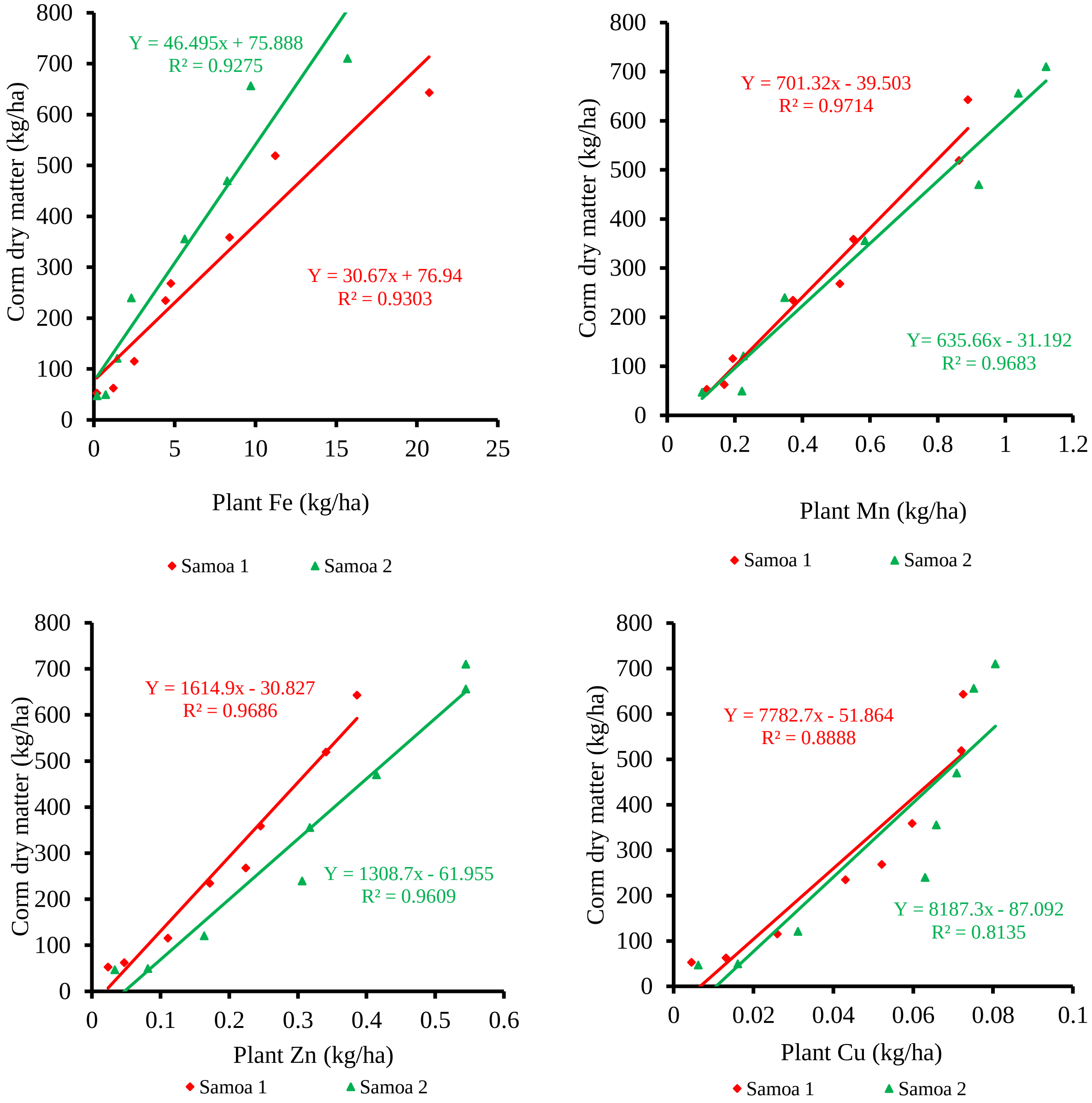

Figure 5 Relationship between corm dry matter yield and micronutrient contents of the two cultivars

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Conclusions

The availability of essential nutrients has been identified as a major limitation to crop productivity in many regions of the tropics. Inorganic fertilisers are seldom applied under traditional farming practices in developing nations, because of their high cost and uncertain availability. Instead, productivity is often maintained by employing systems of bush fallowing, and within a cropping phase, by rotations to match nutrient demand by a crop to soil fertility. However, growing populations and export potential have resulted in a need to increase the productivity of many staple food crops. Therefore, investigations into nutrient use efficiency of improved varieties, merits attention.

This investigations revealed that while the concentrations of all the plant nutrients (except Fe) uptake was higher for cultivar Samoa 2 than cultivar Samoa 1, the nutrient use efficiency (kg of edible dry matter produced per kg of nutrient taken up) for cultivar Samoa 1 was higher for N, P, K, Mg, Mn and Cu over cultivar Samoa 2. However, for Ca, Fe and Zn cultivar Samoa 2 had a higher nutrient use efficiency over cultivar Samoa 1.

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