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GROWTH, YIELD AND NUTRIENT UPTAKE OF TARO GROWN UNDER UPLAND CONDITIONS

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ABSTRACT: There is a scarcity of basic information on dry matter accumulation by various plant organs, nutrient uptake, and yield of taro [*Colocasia esculenta* (L.) Schott] grown under upland conditions. These data are essential for the development of technological packages, growth simulation models, and decision support systems designed to promote agrotechnology transfer of the crop in the tropics. Two taro cultivars were planted and harvested for biomass about every six weeks during the growing season. At each harvest, plants were separated into various plant parts and their dry matter and nutrient content were determined. There were no significant differences ($P<0.05$) in total and edible dry matter content between cultivars. However, cultivar 'Lila' absorbed significantly smaller amounts of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and zinc (Zn) than cultivar 'Blanca', suggesting that it had a higher nutrient-use efficiency. Fresh corm yields were not significantly different and averaged 20,221 kg/ha for both cultivars.

INTRODUCTION

Taro [*Colocasia esculenta* (L.) Schott] is a staple root crop for inhabitants in the Pacific and Caribbean Basins as well as Africa (1). However, current yield levels in taro production are relatively low. On a worldwide basis, the crop yields only about 6,000 kg/ha compared with 14,746 kg/ha for potato (*Solanum tuberosum* L.) and 13,628 kg/ha for sweet potato (*Ipomoea batatas* L.) (2)

In traditional farming situations in the tropics, taro is grown under rainfed conditions which can lead to drastic yield declines as a result of transient drought periods. In addition, yield potential of taro is seldom realized because of lack of knowledge concerning diseases, proper management practices, and physiological determinants that may limit growth and development. There is, therefore, a need to develop technology to improve agricultural production of upland taro and transfer that technology to production sites. A scarcity of information exists regarding nutrient uptake of taro, particularly, under intensive cropping systems which are aimed at satisfying the crop demand of a growing population and supplying corms for export markets. This information is also critical for the establishment of breeding programs aimed at raising the yield potential of taro.

The objective of this study was to determine the growth, nutrient uptake, and yield performance of two taro cultivars grown under intensive management in an initial effort to develop a package of agronomic practices for improved monoculture production of taro under tropical upland conditions. The study also forms part of an ongoing effort to collect growth analysis data to validate the SUBSTOR-Aroid model (1,3).

MATERIALS AND METHODS

The experiment was conducted at the research farm of the USDA-ARS Tropical Agriculture Research Station, Isabela, Puerto Rico. The soil is a well-drained Oxisol (clayey, kaolinitic, isohyperthermic, Tropeptic Eutrustox) with pH = 6.1; bulk density = 1.4 g/cm^3; organic carbon = 2.0%; and exchangeable bases = 8.3 cmol(+)/kg of soil. Preplant soil nitrate and ammonium at the 0-15 cm depth were 11.0 and 9.1 μg/g of soil, respectively. Average monthly rainfall, class A pan evaporation, and air mean temperature throughout the experimental period were 12.9 cm, 13.4 cm, and 24.7°C, respectively. Average monthly solar radiation was 16.8 MJ/m^2.

Taro suckers of cultivars 'Blanca' and 'Lila' were planted in the field on 25 June 1992 and arranged in a split-plot design with five replications. Each replication contained two main plots (cultivars) which were split to accommodate eight biomass harvests. Each subplot contained 20 plants spaced 0.91 x 0.46 m apart, the inner six of which were sampled for biomass production. Twelve plants per plot were harvested from each treatment to calculate final yield. The experiment was surrounded by two rows of guard plants.

Each sucker received 3.5 g of granular P at planting provided as triple superphosphate. Plants were drip irrigated when the soil water tension, measured with tensiometers at a depth of 15 cm exceeded 20 kPa. Throughout the experimental period, fertilization through the drip system was provided biweekly at the rate of 5.6 and 7.6 kg/ha of N and K, respectively, using a mixture of potassium nitrate and urea as the nutrient sources.

Plants were collected and biomass measurements taken at 48, 82, 117, 159, 201, 243, 285, and 327 days after planting (DAP). At each harvest, leaves of plants were cut at the midrib-petiole intersection. Plants in the subplots were then harvested by digging an area of 0.42 m^2 around each plant and to a depth of 30.5 cm. Plants were then pulled from the soil, washed, and separated into petioles, corms, roots and sucker components (cormels, leaves, petioles, and roots). Samples of the various plant parts were dried to constant weight at 70°C for dry matter determination. The dry samples were ground to pass a 1.0-mesh screen and analyzed for N, P, K, Ca, Mg, and Zn. The third uppermost leaf lamina was also analyzed for these elements as well as iron (Fe), manganese (Mn), and copper (Cu) at 85, 127, 165, 211, 239, and 302 DAP. Nitrogen was determined by the micro-Kjeldahl procedure (4), P by the molybdovanadophosphoric acid method (4), and K, Ca, Mg, Zn, Fe, and Mn by atomic absorption spectrophotometry (5). Nutrient content was calculated as the product of dry matter content and tissue nutrient concentration. Analyses of variance and best-fit curves were determined using the ANOVA and GLM procedures, respectively, of the SAS program package (6). Only coefficients significant at $P<0.05$ were retained in the models.

RESULTS AND DISCUSSION

Figure 1A-F shows the accumulation of dry matter in various plant organs of each cultivar. Total dry matter did not differ significantly between cultivars throughout the experimental period (Table 1). The first 82 DAP were characterized by low rates of total dry matter production in both cultivars (Fig. 1A). During this period, leaves and petioles accounted for more than 40% of the total dry matter produced in each cultivar (Figs. 1A-C) . After 201 DAP, the dry matter content in leaves and petioles declined to less than 10% of the total dry matter, but it increased significantly in corms and suckers (Figs. 1E,F). Roots of both cultivars represented about 9% of the total dry matter content during the first 82 DAP; thereafter, this percentage was never higher than 4% (Figs. 1A,D). It is noteworthy that, between 201 and 327 DAP, the suckers were the predominant sink of dry matter in the plant. During this period, these organs accounted for 57% of the total plant dry matter in 'Blanca' and 49% in 'Lila' (Figs. 1A,F). These results are of particular importance because, when taro is grown under upland conditions, cormels of suckers seldom

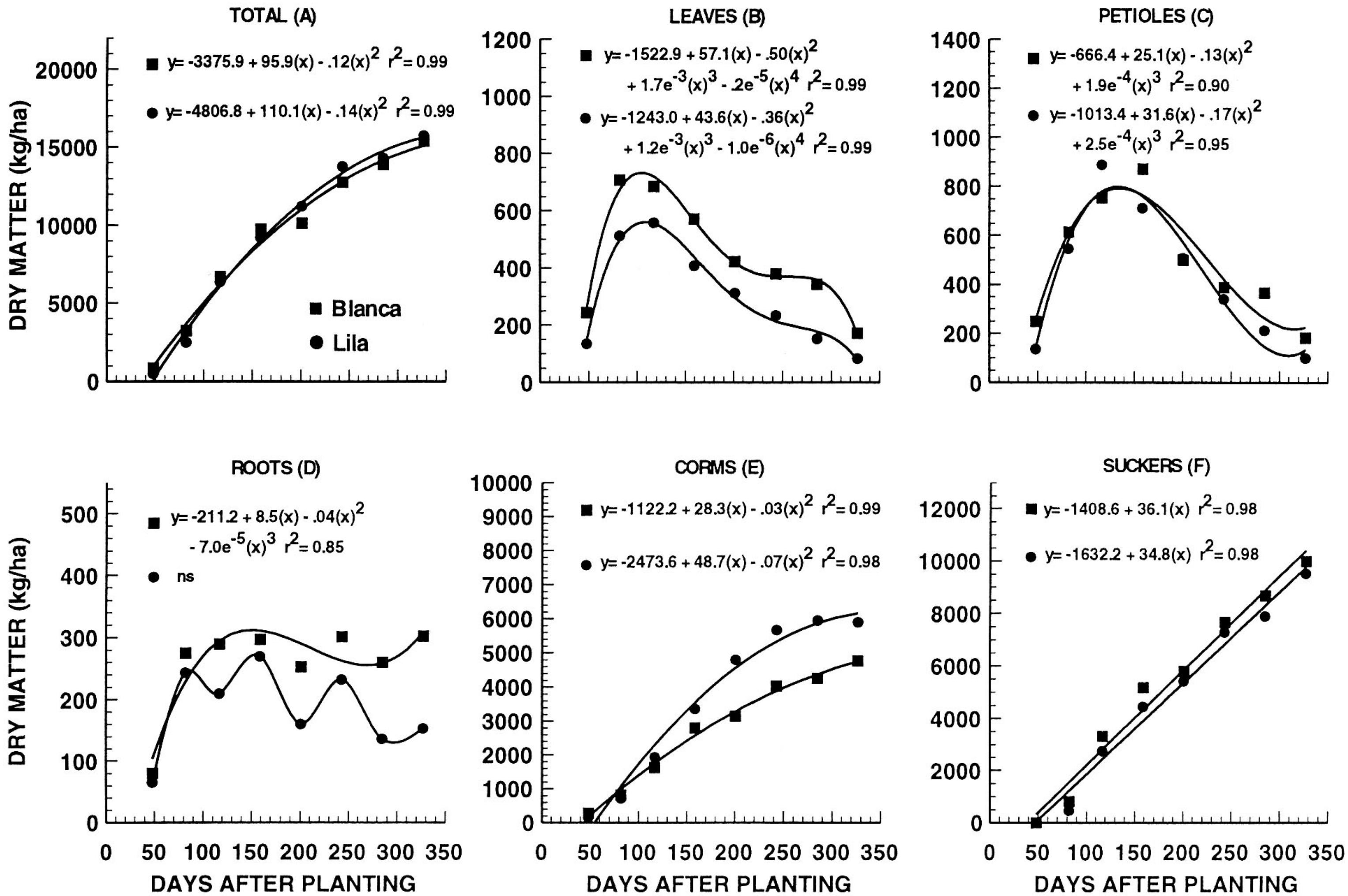

Figure 1. Dry weight of plant organs of two taro cultivars as influenced by plant age. All symbols as in Figure 1A.

Table 1. Analysis of variance for effects of cultivar and days after planting on total dry weight, yield and plant uptake of various nutrients.

		Mean squares							
				Nutrient uptake					
Source	df	Total dry wt.	Yield	N	P	K	Ca	Mg	Zn
Replication	4	3018319	1662769	855**	25	1956	73	22*	.089***
Cultivar (CV)	1	244686	6018815	7631*	1267***	102357***	11850**	$9.8e^{-5}$	.081*
Error a	4	2251190	5837441	649	14	1086	211	22	.010
Days after planting (DAP)	7	290902874***	472423359***	36411***	4185***	101929***	5457***	650***	.708***
CV x DAP	7	1210192	3326881	832**	118***	6208***	578***	18*	.020
Error b	56	1618772	4842119	259	1267	989	72	7	.012

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

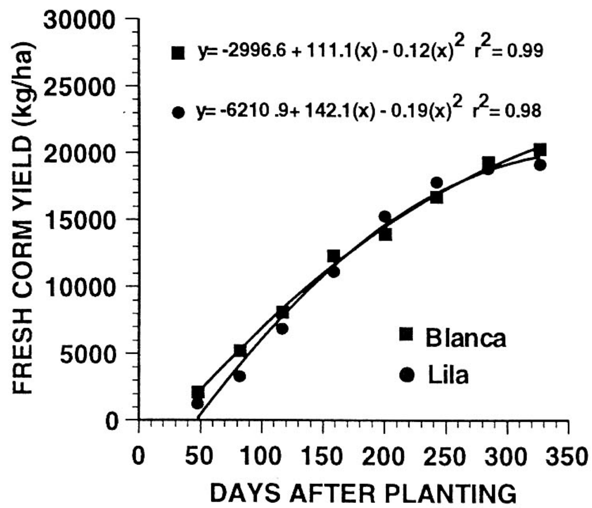

FIGURE 2. Fresh corm yields of two taro cultivars as influenced by plant age.

reach a marketable size; and they may compete for assimilates with the marketable main-plant corm.

Maximum fresh corm yields of 20, 502, and 19,939 kg/ha were obtained at 327 DAP for cultivars 'Blanca' and 'Lila', respectively (Fig. 2). Yield differences between cultivars were not significantly different throughout the experimental period (Table 1)

Except for Mg, the quantity of nutrients taken up by plants was significantly different between cultivars (Table 1). In general, nutrient uptake was very similar between cultivars during the first 159 DAP; thereafter, the quantity of N, P, K, Ca, and Zn taken up by plants of cultivar 'Lila' was significantly lower (Figs. 3A-F). A total of 463 kg/ha of potassium nitrate and 154 kg/ha of urea was supplied to both cultivars through the drip irrigation system during the growing season. These quantities supplied 131 and 177 kg/ha of N and K, respectively. Maximum nutrient uptake values for cultivar 'Blanca' were 208 kg/ha N, 70 kg/ha P, 376 kg/ha K, 106 kg/ha Ca, 24 kg/ha Mg, and 0.88 kg/ha Zn. Maximum uptake values were considerably smaller in 'Lila' plants which absorbed 154 kg/ha N, 48 kg/ha P, 254 kg/ha K, 62 kg/ha Ca, 25 kg/ha Mg, and 0.71 kg/ha Zn. It is noteworthy that

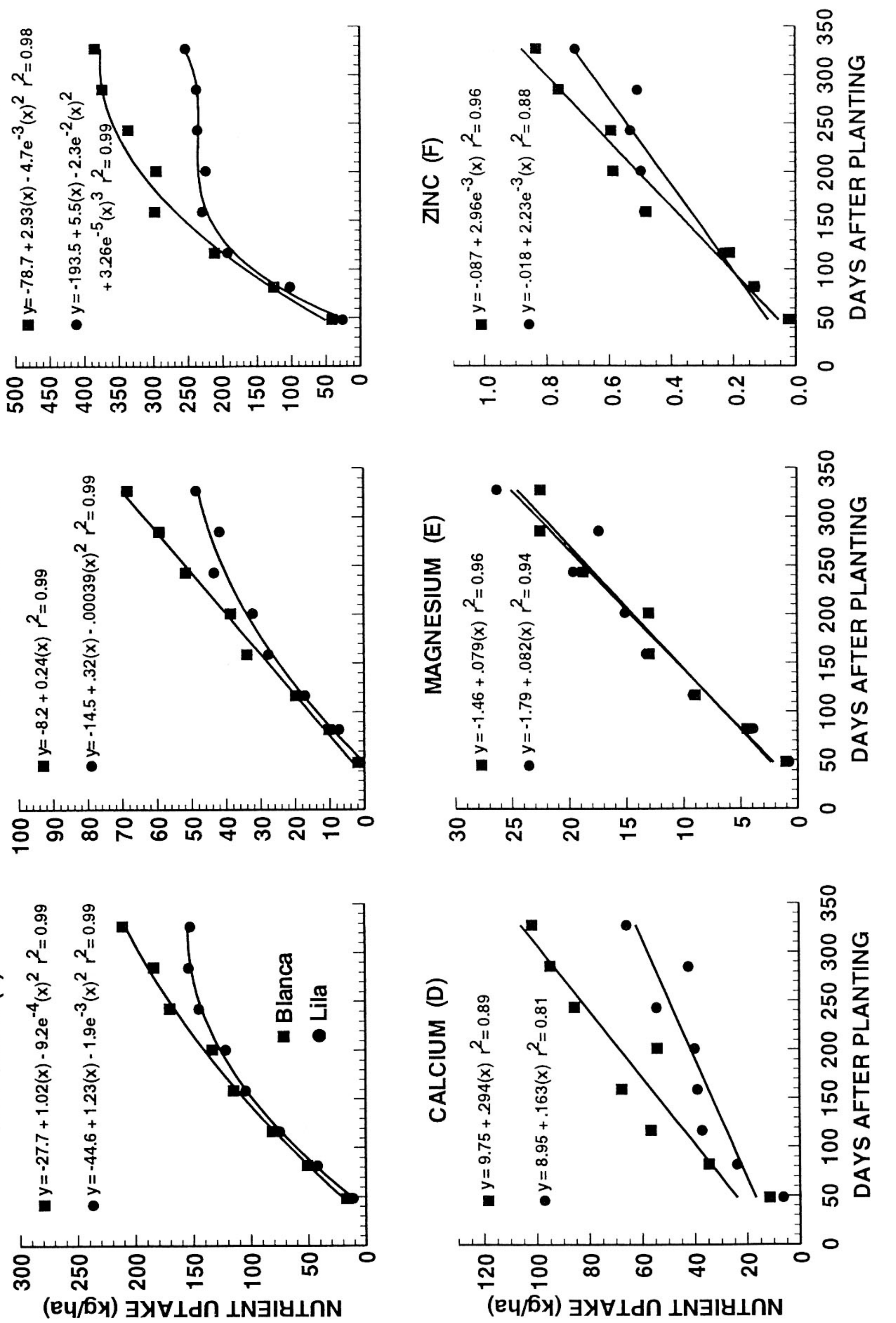

FIGURE 3. Nutrient content of two taro cultivars as influenced by plant age. All symbols as in Figure 1A.

'Lila' plants absorbed 32% less K than those of 'Blanca', and 90% of the total K taken up by 'Lila' was absorbed by 159 DAP. Similarly, 'Lila' plants required 26% less N than 'Blanca', and 80% of the total N was absorbed by 201 DAP. These results also show that, as with most root crops, taro has a high requirement for K relative to N (1,7,8). Regardless of the cultivar, by 327 DAP corms and cormels had accumulated about 35% and 53%, respectively, of the total nutrients taken up by the plants.

Since the total dry matter content was similar for both cultivars (Table 1; Fig. 1A), the higher uptake of nutrients exhibited by cultivar 'Blanca' (Figs. 3A-F) can only be confirmed by a higher concentration of nutrients in particular plant organs of this cultivar. For example, the concentration of K was very similar in most organ tissues of both cultivars; however, after 82 DAP, it was 43% higher in the cormels of 'Blanca' suckers (data not shown). Similarly, a higher uptake of Ca in 'Blanca' (Fig. 3D) was the result of an average concentration of the nutrient in its corms that was 60% greater than in those of 'Lila'.

The third uppermost leaf lamina is often used to determine the nutritional status of aroid crops including taro (7,9,10). In general, the concentration of N, K, Mg, Zn, and Cu in this leaf lamina of 'Lila' plants was higher than in its counterpart in 'Blanca', whereas the latter had a greater concentration of P, Ca, and Fe (Table 2) . We are not aware of similar nutritional data for field-grown taro with which comparisons could be made. Experiments conducted at the same location with the aroid *Xanthosoma* showed similar N, K, and Ca leaf tissue concentrations but considerably lower concentrations of P, Mg, and Zn at similar stages of growth (7).

Since there were no significant differences in total and corm dry matter production between cultivars (Table 1), it could be concluded that cultivar 'Lila' had a higher nutrient use efficiency (kg of edible dry matter produced per kg of nutrient taken up) than cultivar 'Blanca' (Figs. 4A-F) . These ratios were significantly greater in cultivar 'Lila' than in 'Blanca' for all the nutrients tested (data not shown). By 327 DAP, the efficiency ratios for N, P, K, Ca, Mg, and Zn were higher in 'Lila' than in 'Blanca' by 69, 74, 88, 90, 3.5, and 44%, respectively (Fig. 4).

Efficiency ratios can be influenced by the duration of the crop, fertilization, amount of solar radiation, and drought (11). Therefore, comparison of ratios among species or cultivars and across environments or management practices should be conducted with caution. In this experiment, the cultivars were grown

Table 2. Percent nutrient concentration in the lamina of the third uppermost leaf of taro cultivars Lila and Blanca at various stages of growth.

Days after planting	Cultivar	Nutrient								
		N	P	K	Ca	Mg	Zn	Fe	Mn	Cu
		(%)								
85	Blanca	4.2	.34	4.2	2.1	.22	.0021	.0121	.0344	.0012
	Lila	4.5	.30	3.7	1.8	.30	.0027	.0010	.0485	.0027
127	Blanca	3.5	.37	3.1	2.5	.23	.0013	.0082	.1184	.0008
	Lila	4.3	.35	3.0	1.3	.25	.0027	.0065	.1182	.0016
165	Blanca	3.6	.36	3.2	2.6	.27	.0021	.0157	.0976	.0009
	Lila	3.9	.32	3.6	2.1	.30	.0026	.0124	.0898	.0011
211	Blanca	4.0	.41	2.7	2.3	.23	.0017	.0100	.1391	.0008
	Lila	4.1	.34	3.5	1.8	.26	.0028	.0096	.1290	.0012
239	Blanca	3.7	.40	3.0	2.2	.22	.0019	.0146	.1167	.0009
	Lila	4.1	.37	3.6	1.8	.27	.0029	.0114	.1196	.0010
302	Blanca	3.3	.40	3.3	3.6	.28	.0017	.0101	.0953	.0008
	Lila	3.6	.31	3.0	2.5	.38	.0025	.0081	.1366	.0008

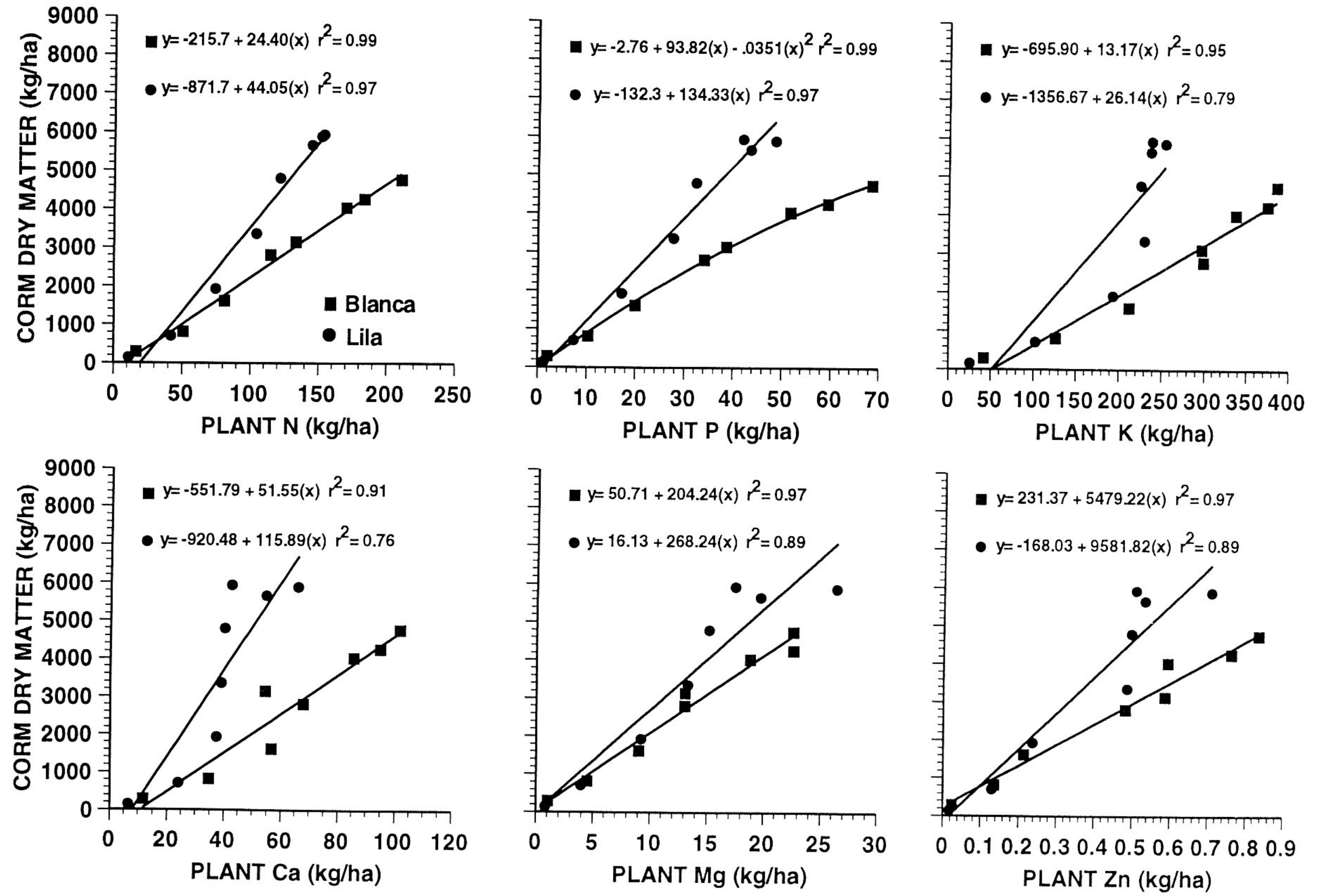

FIGURE 4. Relationship between corm dry matter yield and nutrient content of two taro cultivars. All symbols as in Figure 1A.

under identical conditions; however, future experimentation using a more limited nutrient supply should confirm the superior nutrient use efficiency of cultivar 'Lila'. Results from these investigations could be valuable for breeding programs dealing with taro improvement.

CONCLUSION

Only a few experiments characterizing the interrelationship between growth and development and nutrient uptake of upland taro have been reported in the literature. This is not surprising since taro and aroids in general are mainly grown in the tropics as subsistence crops. As the demand for taro increases, local and export market needs will only be met through extensive plantings using modern technology. Implementation of such technology will require that we readdress current cultural and management practices and enhance basic research to achieve higher yields.

The results of this study demonstrate varietal differences in nutrient uptake and patterns of dry matter accumulation in various plant components of taro plants. Information obtained is currently being used as part of a data base on taro for the validation of the SUBSTOR-Aroid model which was developed to improve agrotechnology transfer of the crop.

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