Growth, nutrient uptake and yield of tanier (*Xanthosoma* spp.) grown under semiarid conditions[1,2]

Ricardo Goenaga[3]

ABSTRACT

There is little information regarding optimum water requirement for tanier grown under semiarid conditions with irrigation. A study was conducted to determine the growth, nutrient uptake and yield performance of tanier plants irrigated with the equivalent of fractions of evapotranspiration. The irrigation regimes were based on class A pan factors ranging from 0.33 to 1.32 with increments of 0.33. Tanier plants grown under field conditions were harvested for biomass production about every 6 weeks during the growing season. At each harvest, plants were separated into various plant parts to determine dry matter accumulation, N, P, K, Ca, Mg, and Zn uptake and yield. During the first 278 days after planting, plants replenished with 99 and 132% of the water lost through evapotranspiration (WLET) exhibited similar total dry matter content; however, their dry matter content was significantly greater than that in plants supplied with 33 and 66% WLET. The amount of N, P, K, Ca, Mg, and Zn taken up by plants replenished with 99 and 132 WLET was similar, whereas the content of these nutrients in plants replenished with 33 and 66% WLET was considerably lower. The yield of plants replenished with 99% WLET was considerably greater than that of plants supplied with 33 and 66% WLET, but significantly lower than that from plants receiving 132% WLET. Maximum cormel yields of 19,479 kg/ha were obtained from plants replenished with 132% WLET.

RESUMEN

Crecimiento, extracción de nutrimentos y rendimiento de yautía (*Xanthosoma* spp.) producida bajo condiciones semiáridas.

Hay muy poca informacion sobre los requisitos de riego para yautía producida en zonas semiáridas. Se hizo un estudio para determinar el crecimiento, la extracción del suelo de varios nutrimentos y el rendimiento de yautía irrigada con cantidades de agua equivalentes a fracciones de la evapotranspiracion. Los tratamientos de riego se basaron en coeficientes de evapotranspiración (medidos con un evaporímetro clase A) que fluctuaron desde 0.33 hasta 1.32 con incrementos de 0.33. Se sembraron plantas de yautía en el campo y se cosecharon aproximadamente cada 6 semanas. En cada cosecha se determinó la acumulación de materia seca en varios órganos de las plantas, la extracción de N, P, K, Ca, Mg y Zn y el rendimiento comercial de cormelos. Durante los primeros 278 días después de la siembra,

---

[1] Manuscript submitted to the Editorial Board 9 November 1993.

[2] The author acknowledges the excellent field assistance of Roberto Bravo, Vidal Martí, Roberto Luciano and Tomás Miranda during the course of this investigation.

[3] Research Plant Physiologist, USDA-ARS, Tropical Agriculture Research Station, Mayagüez, Puerto Rico, 00681-0070.

las plantas regadas con el 99 y el 132% del agua evapotranspirada (AE) exhibieron contenidos totales de materia seca similares; sin embargo el contenido de materia seca en éstas fue significativamente mayor que en plantas que recibieron 33 y 66% de AE. La extracción de N, P, K, Ca, Mg y Zn en plantas que recibieron el 99 y el 132% del AE fue similar; por otro lado el contenido de estos nutrimentos en plantas que recibieron el 33 y el 66% del AE fue considerablemente menor. El rendimiento de plantas que recibieron el 99% del AE fue mayor que el de las plantas que recibieron 33 y 66% AE, pero significativamente menor que el obtenido en plantas irrigadas con el 132% del AE. El rendimiento comercial más alto, 19,479 kg/ha, se obtuvo en plantas irrigadas con el 132% del AE.

INTRODUCTION

Tanier (*Xanthosoma* spp.) is a herbaceous perennial root crop that serves as an important food staple in some subtropical and virtually all tropical regions. In Puerto Rico, tanier ranks second in economic importance among root crops (14). The major production area is the mountain region where periodic droughts often reduce yields. The demand for a year-round supply of high quality cormels, high farm-gate prices, and the availability of arable land with an irrigation infrastructure has generated interest among farmers and government agencies to shift tanier production from the highlands to the fertile but semiarid lowlands previously used for sugarcane production. In a normal year, evaporation in this agricultural zone may be three times greater than rainfall.

Drip irrigation technology allows efficient use of water and may maximize the utilization of semiarid land for agricultural production. There is little information regarding water requirements for optimum tanier production in Puerto Rico or elsewhere in the tropics, particularly under semiarid conditions.

It has been suggested that the water needs of tanier are ideally supplied by 140 to 200 mm of evenly distributed rainfall throughout the year (13). The importance of adequate soil moisture for tanier growth was demonstrated by Lugo et al. (10), who found that tanier marketable yields were significantly higher in plots that received frequent irrigation. Under field conditions without irrigation, corms and cormels of tanier plants accumulated most of their dry matter at 16 to 20 weeks after planting, but maximal leaf area was attained at 14 weeks after planting and then declined rapidly (9). Maximum yield potential was not attained because of the rapid decline in leaf area during the corm and cormel bulking period.

Experiments conducted in Puerto Rico have demonstrated that tanier yields as high as 34,000 kg/ha can be attained when the crop is grown with drip irrigation and intensive management (5,6). Under rainfed conditions in Africa and many Caribbean countries, tanier yields are very low, ranging from 1,270 to 5,440 kg/ha (11). These results illustrate the importance of tanier irrigation and suggest that the potential for commercial production of tanier depends on the implementation of management practices that prevent stress conditions during tanier growth, particularly if the goal is to increase food production for the growing population in the tropics.

This study was undertaken to determine the growth, nutrient uptake and yield performance of tanier grown in fertile but semiarid lands and subjected to various irrigation regimes. The study also forms part of a continued effort to collect growth analysis data to develop the SUBSTOR-Aroid model (6,16).

MATERIALS AND METHODS

A field experiment was conducted at the Agriculture Experiment Station of the University of Puerto Rico at Fortuna, Juana Diaz. The soil is a well-drained Mollisol (fine-loamy, mixed, isohyperthermic Cumulic Haplustoll) with pH 6.8, bulk density of 1.56 g/cm^3; organic carbon, 1.7%; and exchangeable bases, 23.2 cmol (+)/kg of soil. Soil nitrate and ammonium at the 0 to 15 cm depth were 11.2 and 12.9 μg/g of soil, respectively.

Plants of cultivar Blanca were established in a screenhouse from excised corm buds with fresh weights of about 16 g (2.7 g dry weight) and planted in plastic trays containing Pro-Mix growing medium. On 11 September 1991, plants at the one-leaf stage were transplanted to the field and arranged in a split-plot design with five replications. Each replication contained four main plots representing different moisture regimes. The main plots were split to accommodate nine 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. An alley of 2.7 m separated the main plots to prevent overlapping of water between treatments. The experiment was surrounded by two rows of guard plants.

The amount of irrigation applied to plants was calculated with the equation of Young and Wu (18). The equation assumes that the evapotranspiration of a tanier plant is equal to the evaporation from a body of water with a free surface equal to the plant area as determined by a Class A pan evaporimeter. In this study, the equation was modified to include a pan coefficient (Kp) value of 0.70 and a crop coefficient (Kc) value of 0.87 to obtain a theoretical value of potential evapotranspiration (3). Class A pan factors, which ranged from 0.33 for treatment 1 (increasing by 0.33 per treatment) to 1.32 for treatment 4, were used to obtain fractions of the potential evapotranspiration. A pan factor of 0.33 means that the irrigation applied to the plants would replace 33% of the water lost through evapotranspiration (WLET).

Plants were subjected to one of the four moisture regimes 7 weeks after field planting. The amount of water applied varied weekly depending on Class A pan evaporation and rainfall. Evaporation and rainfall data of each week were used to determine the irrigation needs for the next week. Irrigation was supplied three times per week on alternate days, and no irrigation was provided when the total rainfall exceeded 20 mm per week.

The water source was a well-fed reservoir. Submain lines equipped with volumetric metering valves to monitor the water from the main line were provided for each treatment. Lateral lines equipped with 8-L emitters spaced 45.7 cm apart branched out from the submains along each plant row.

At planting, each plant received 3.5 g of granular P provided as triple superphosphate. Throughout the experimental period, fertigation was provided monthly at the rate of 3.7 and 8.0 kg/ha of N and K, respectively, with potassium nitrate and urea as the nutrient sources. Fertilization also included 0.45 and 0.13 kg/ha of Zn and Fe, respectively, supplied in their EDTA chelate forms and 0.48 kg/ha of Mn supplied as DTPA chelate.

Samples for plant and biomass measurements were collected at 49, 91, 133, 181, 223, 278, 322, 364 and 398 days after planting (DAP), except for treatments 1 and 2, in which the last biomass harvest was made at 364 DAP.

At each harvest, leaves of plants were cut at the midrib-petiole intersection. Plants in the subplots were harvested by digging an area of 0.42 m^2 around each plant to a depth of 30.5 cm. Because of the labor and carefulness required during the root sampling operation, only two plants were used for that purpose. Plants were then pulled from the soil, washed, and separated into petioles, corms, cormels, roots and suckers. Samples were dried to constant weight at 70° C for dry matter determination. The dry samples were ground to pass a 1.0-mil mesh screen and analyzed for N, P, K, Ca, Mg and Zn. Nitrogen was determined by the micro Kjeldahl procedure (12), P by the molybdovanadophosphoric acid method (8) and K, Ca, Mg and Zn by atomic absorption spectrophotometry (2).

Analyses of variance and best fit curves were determined with the ANOVA and GLM procedures, respectively, of the SAS program package (15). Only coefficients significant at $P \leq 0.05$ were retained in the models.

RESULTS AND DISCUSSION

Dry matter accumulation

Total class A pan evaporation was two times greater than the amount of total rainfall recorded during the experimental period (table 1). Under those conditions large soil-water deficits would have existed without irrigation. The average evaporation and rainfall data collected during the same period for over 20 years were 2,482 mm and 1,212 mm, respectively (7). These figures are similar to those obtained during the experimental period, which can therefore be considered as a normal one.

There were no significant differences in total dry matter production among treatments during the first 91 DAP (fig. 1). This growth period was characterized by low rates of total dry matter production with leaves and petioles accounting for over 70% of the total dry matter pro-

TABLE 1.—*Monthly evaporation and rainfall registered at the Fortuna Substation and the amount of water applied to four irrigation treatments throughout the tanier-growing cycle (1991-92).*

			Irrigation supplied (liters/plant)			
			Pan factor			
Month	evaporation (*mm*)	rainfall (*mm*)	0.33	0.66	0.99	1.32
Sep.	183.6	55.1	-	-	-	-
Oct.[a]	182.6	45.5	18.0	36.0	54.0	72.0
Nov.	153.2	82.0	3.4	6.8	10.2	13.6
Dec.	134.1	5.1	7.4	14.8	22.2	29.6
Jan.	134.6	228.3	4.0	8.0	12.0	16.0
Feb.	160.0	20.3	11.1	22.2	33.3	44.4
Mar.	196.8	18.5	16.2	32.4	48.6	64.8
Apr.	184.7	78.0	4.8	9.6	14.4	19.2
May	169.2	471.9	7.8	15.6	23.4	31.2
June	202.4	33.5	9.0	18.0	27.0	36.0
July	232.2	3.3	20.1	40.2	60.3	80.4
Aug.	207.5	85.1	11.3	22.6	33.9	45.2
Sep.	177.5	99.1	2.9	5.8	8.7	11.6
Oct.	160.3	171.2	0	0	0	0
Total	2478.7	1396.9	116.0	232.0	348.0	464.0
Average	177.0	99.8	8.9	17.8	26.8	35.7

[a] Initiation of irrigation treatments. Previously, the experimental area was sprinkled-irrigated until establishment of the crop.

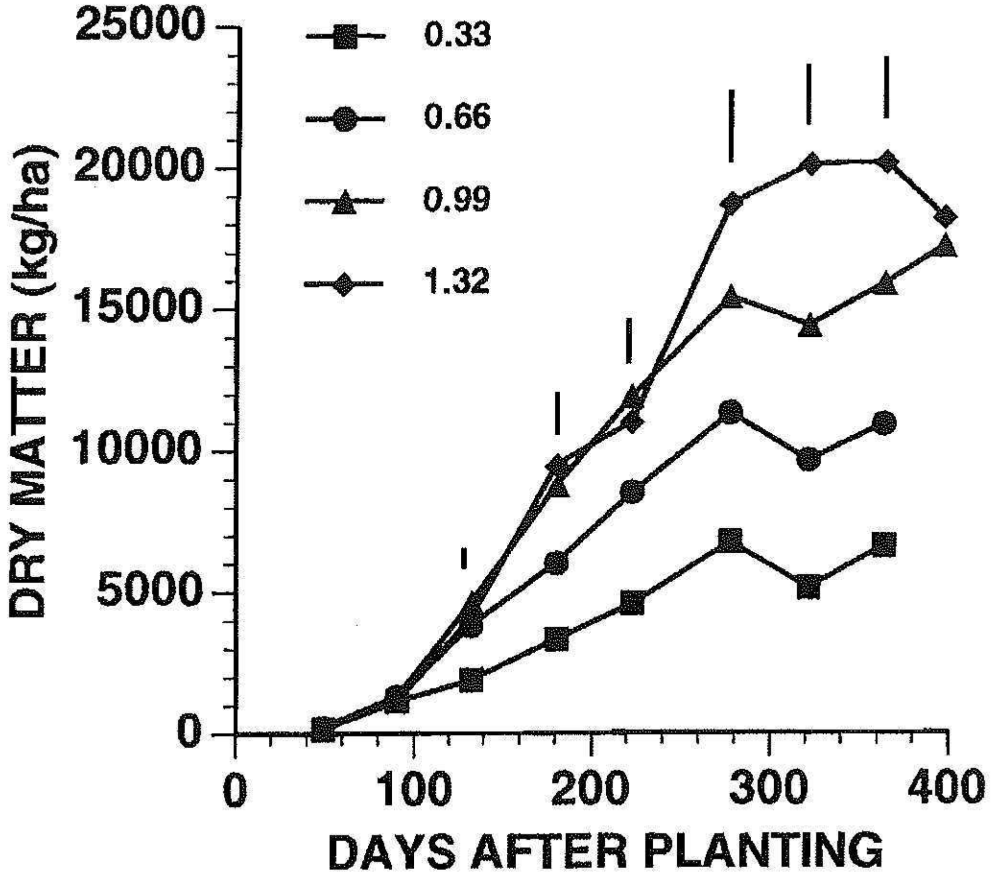

FIG. 1. Accumulation of total dry matter in tanier as influenced by plant age and irrigated with fractions of evapotranspiration. The vertical bars are significant Fisher's lsd values at P=0.05; absence of bars denotes lack of significant differences.

duced (fig. 2A-B). Between 91 and 223 DAP, plants that received 99 and 132% (i.e., pan factors of 0.99 and 1.32) of the water lost through evapotranspiration (WLET) exhibited similar amounts of total dry matter (fig. 1). During this period, roots and corms from most treatments showed high rates of dry matter accumulation whereas growth of cormels was severely affected in plants receiving the low irrigation treatments (fig. 2C-E). By 223 DAP, the average production of total dry matter from plants replenished with 99% WLET was 26% greater than that from those replenished with 66% WLET; total dry matter from plants replenished with 132% WLET was 60% greater than that produced by plants replenished with 33% WLET.

Cormel development was initiated at 91 DAP regardless of the irrigation treatment imposed on plants. This finding indicates that the initiation of cormel development is insensitive to water stress conditions. The importance of proper irrigation during the cormel bulking

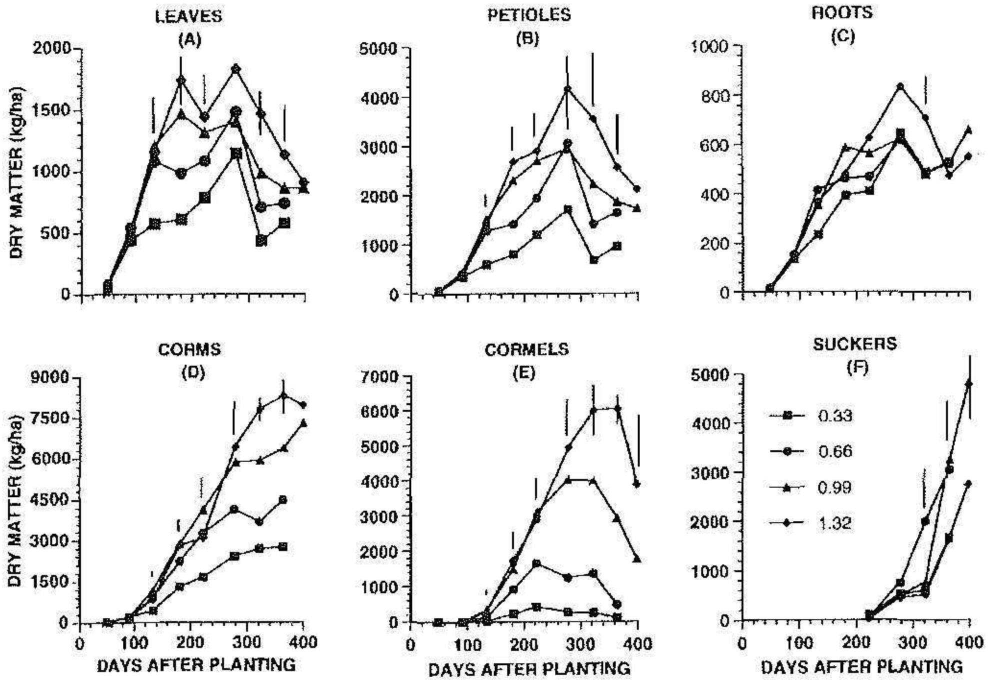

FIG. 2. Accumulation of dry matter in tanier as influenced by plant age and irrigated with fractions of evapotranspiration. All symbols as in figure 1-F. The vertical bars are significant Fisher's lsd values at P=0.05; absence of bars denotes lack of significant differences.

period was manifested by the low rates of dry matter accumulation in cormels from plants replenished with 33 and 66% WLET (fig. 2E). By 223 DAP, cormel dry matter in plants receiving 33 and 66% WLET was 86 and 45% less than in those that received 99% WLET. Results published elsewhere (4) showed that leaf area indices were considerably lower in plants subjected to 33 and 66% WLET. As a result, the potential contribution of leaf assimilates toward the cormels was reduced, resulting in a drastic decline of cormel dry matter in these treatments. Cormel dry matter production was also influenced by water stress conditions which caused cormel sprouting and consequent sucker development (fig. 2E). By 364 DAP, suckers were more than 20% of the total dry matter in plants replenished with 33 to 99% WLET, but only 8% in those receiving 132% WLET.

Nutrient uptake

Figure 3A-F shows that nutrient uptake increased steadily during most of the growing season. The amount of N, P, K, Ca, Mg and Zn taken up by plants replenished with 99 and 132% WLET was similar, whereas the content of these nutrients in plants replenished with 33

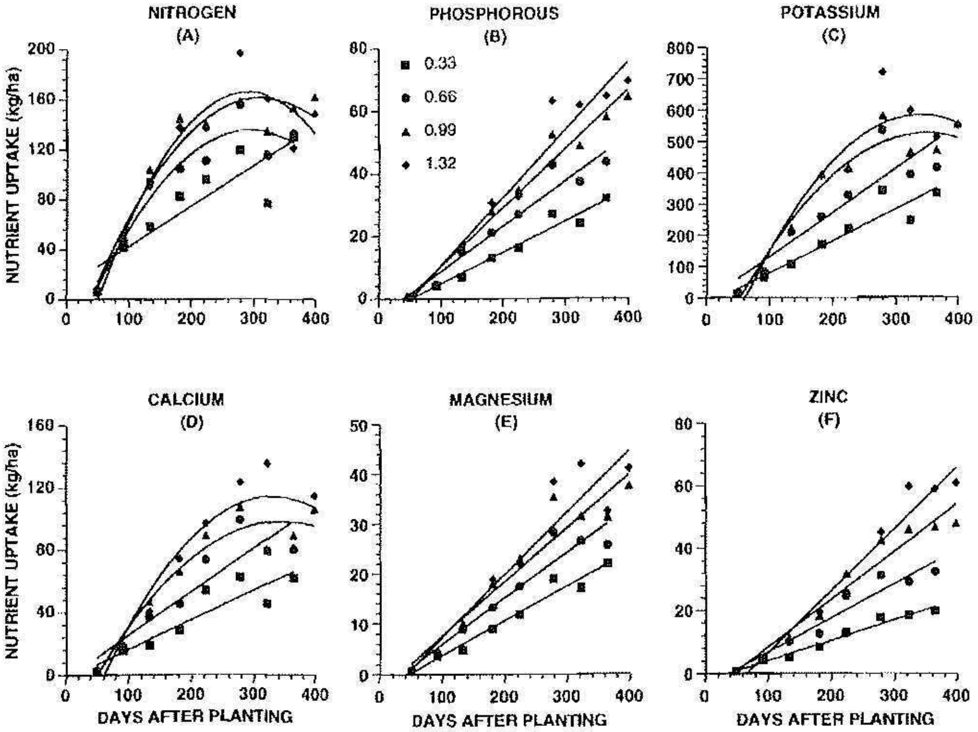

FIG. 3. Nutrient content in tanier cultivars as influenced by plant age and irrigated with fractions of evapotranspiration. All symbols as in figure 3-B.

and 66% WLET was considerably lower (fig. 3A-F). Plants from the latter treatments exhibited lower nutrient contents because of their lower production of dry matter rather than by a reduced concentration of nutrients in the tissue (fig. 2A-F and table 2).

Maximum uptake values for plants replenished with 132% WLET were 165 kg/ha N, 76 kg/ha P, 582 kg/ha K, 114 kg/ha Ca, 44 kg/ha Mg and 65 kg/ha Zn. Similar studies (5) conducted in an Oxisol showed higher values for N, Mg and Zn; similar values for P and Ca and lower values for K. In that study, a total of 185 and 232 kg/ha of N and K, respectively, were supplied from fertilizer sources. The fact that only 49.4 and 105.8 kg/ha of N and K, respectively, were provided from fertilizer sources in this study indicates that soils in this agricultural zone are highly fertile.

Yield performance

Large significant differences for cormel yield and number of cormels were observed among irrigation treatments (table 3). Cormel yield and cormel number in plants replenished with 33 and 66% WLET were extremely low. The yield of plants that received 99% WLET was

TABLE 2.—*Average percentage nutrient concentration in leaf laminas of tanier plants replenished with fractions of evapotranspiration.*

Nutrient	Treatment	DAYS AFTER PLANTING								
		49	91	133	181	223	278	322	364	398
N	.33	4.65	4.72	4.75	4.06	3.82	3.80	3.49	3.66	-
	.66	4.50	4.62	4.20	3.67	3.45	3.63	3.35	3.29	-
	.99	4.31	4.62	4.16	3.71	3.37	3.40	3.19	3.26	3.55
	1.32	4.57	4.53	4.09	3.40	3.20	3.35	2.97	3.25	3.48
P	.33	.35	.37	.37	.38	.31	.42	.39	.36	-
	.66	.34	.38	.43	.40	.35	.43	.39	.35	-
	.99	.32	.38	.41	.40	.35	.41	.40	.37	.46
	1.32	.34	.37	.44	.40	.35	.43	.39	.44	.51
K	.33	4.55	4.60	4.53	4.55	4.28	4.92	3.84	3.83	-
	.66	5.41	4.66	4.51	4.22	4.24	4.84	4.01	3.78	-
	.99	5.24	4.52	4.61	4.52	4.09	4.85	3.95	3.74	3.96
	1.32	4.77	4.52	4.50	4.40	3.99	4.62	4.15	3.84	4.08
Ca	.33	1.92	1.91	1.52	1.14	1.74	1.77	1.86	1.44	-
	.66	1.97	1.72	1.46	1.24	1.78	1.90	1.76	1.85	-
	.99	2.16	1.91	1.82	1.34	1.88	1.85	1.97	2.06	1.84
	1.32	1.95	1.89	1.69	1.39	1.99	1.99	2.07	1.97	1.83
Mg	.33	.29	.30	.23	.27	.28	.30	.37	.27	-
	.66	.30	.29	.22	.25	.28	.32	.34	.33	-
	.99	.31	.28	.23	.22	.26	.32	.36	.36	.33
	1.32	.29	.29	.22	.20	.24	.30	.35	.33	.36
Zn	.33	.0035	.0046	.0035	.0038	.0046	.0046	.0053	.0048	-
	.66	.0032	.0048	.0037	.0036	.0047	.0050	.0048	.0049	-
	.99	.0028	.0051	.0036	.0036	.0048	.0048	.0048	.0054	.0064
	1.32	.0031	.0004	.0032	.0039	.0037	.0050	.0047	.0052	.0058

TABLE 3.—*Marketable cormels (no./ha) and marketable yield (kg/ha) of tanier as influenced by irrigation and plant age.*

	Pan factor treatment									
Days after planting	0.33	0.66	0.99	1.32	LSD[a]	0.33	0.66	0.99	1.32	LSD
	Number of cormels					Yield[b]				
181	0	0	7,970	11,956	8,161	0	0	1,128	1,790	1,197
223	797	12,753	38,258	33,476	12,094	114	2,083	7,160	6,058	2,540
278	1,594	15,941	54,996	64,560	15,288	342	2,880	11,423	14,827	3,798
322	0	10,361	45,431	70,139	19,370	0	1,815	10,990	17,885	4,402
364	0	3,985	33,476	74,124	11,086	0	606	7,773	19,479	2,943
398	--	--	25,505	56,590	35,407	--	--	5,368	12,172	6,699

[a] Fisher's (protected) LSD, significant at P=0.05.

[b] Cormels were considered marketable when they attained a weight of 130 g or more.

considerably higher than that of plants replenished with 33 and 66% WLET, but significantly lower than that from plants that received 132% WLET. Maximum cormel yields of 19,479 kg/ha were obtained at 364 DAP in plants replenished with 132% WLET.

The yields obtained in this investigation were higher than those obtained at the same location (10) and in other studies conducted in the humid mountain region of Puerto Rico (1,17). However, maximum yields in other studies (5) with the same tanier cultivar grown in an Oxisol soil under drip irrigation were 16% higher than those obtained in this study.

The results reported in this study demonstrate that profitable tanier yields can be attained in the semiarid agricultural zone of Puerto Rico if proper irrigation and cultural practices are followed. Assuming that a grower can achieve the highest yields obtained in this study and farm gate prices are $0.88 per kilogram of commercial cormels, then gross income of $17,140 per hectare can be attained.

This study also supports the concept that the potential for profitable tanier production in Puerto Rico depends on the intensive management of the crop through the use of modern and efficient agrotechnology. It should be noted, however, that for tanier production in Puerto Rico, alternate sites to the semiarid zone should also be considered because higher yields have been obtained at other agricultural zones with less dependency on irrigation (5).

LITERATURE CITED

1. Abruña, F., J. Vicente-Chandler, E. Boneta and S, Silva, 1967. Experiments on tanier production with conservation in Puerto Rico's mountain region. *J. Agric. Univ. P.R.* 51(2):167-175.
2. Chapman, H.D. and P.F. Pratt, 1961. Methods of Analysis for Soils, Plants, and Water. Division of Agricultural Sciences, University of California, Riverside, CA.
3. Doorenbos, J., and W.O. Pruitt, 1977. Guidelines for Predicting Crop Water Requirements; Irrigation and Drainage Paper 24, FAO, United Nations, Rome, Italy.
4. Goenaga, R. 1994. Partitioning of dry matter in tanier (*Xanthosoma* spp.) irrigated with fractions of evapotranspiration. Annals of Botany. Vol. 73:257-261.
5. Goenaga, R. and U. Chardon. 1993. Nutrient uptake, growth and yield performance of three tanier (*Xanthosoma* spp.) cultivars grown under intensive management. *J. Agric. Univ. P.R.* 77(1-2):1-10.
6. Goenaga, R., U. Singh, F.H. Beinroth and H. Prasad, 1991. SUBSTOR-Aroid: A model in the making. *Agrotechnology Transfer* 14:1-4.
7. Goyal, M.R. and E.A. González, 1989. Climatological Data Collected in the Agricultural Experiment Stations of Puerto Rico. Publication 88-70. Agricultural Experiment Station, College of Agricultural Sciences, Mayaguez, Puerto Rico (Spanish).
8. IBSNAT, 1987. Field and laboratory methods for IBSNAT. Technical Report 2. De-

partment of Agronomy and Soil Science, College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii

9. Igbokwe, M.C., 1983. Growth and development of *Colocasia* and *Xanthosoma* spp. under upland conditions. *In*: E.R. Terry, E.V. Doku, O.B Arene and N.M. Mahungu (eds.), Tropical Root Crops: Production and Uses in Africa. Proc. Second Triennial Symp. of the Int. Soc. for Trop. Root Crops, Douala, Cameroon.
10. Lugo, W.I., H. Lugo-Mercado, J. Badillo, A. Beale, M. Santiago and L. Rivera, 1987. Response of tanier to different water regimes. *In*: B.R. Cooper and R. Patterson (eds.), Twenty-Sixth Annual Meeting of the Caribbean Food Crops Society. Saint John, Antigua.
11. Lyonga, S.N. and S. Nzietchueng. 1986. Cocoyam and the African Food Crisis. *In*: E.R. Terry, M.O. Akoroda, and O.B. Arene (eds.), Tropical Root Crops: Root Crops and the African Food Crisis. Proc. Third Triennial Symp. of the Intl. Soc. for Trop. Root Crops. Owerri, Nigeria.
12. McKenzie, H.A. and H.S. Wallace, 1954. The Kjeldahl determination of nitrogen: a critical study of digestion conditions-temperature, catalyst, and oxidizing agent. *Australian Journal of Chemistry* 7(1):55-70.
13. National Academy of Sciences. 1978. Underexploited tropical plants with promising economic value. Washington, D.C.
14. Ortiz-Lopez, J. 1990, Farinaceous Crops. p. 114-164. In: Situation and Perspectives of Agricultural Commodities in Puerto Rico During 1988-89. Agricultural Experiment Station, College of Agricultural Sciences, Mayaguez, Puerto Rico (Spanish).
15. SAS Institute, Inc. 1987. SAS/STAT Guide for Personal Computers, Raleigh, North Carolina.
16. Singh, U., G.Y. Tsuji, R. Goenaga and H.K. Prasad, 1992. Modeling growth and development of taro and tanier. p. 45-56. *In*: U. Singh, ed. Proc. Workshop on Taro and Tanier modeling, College of Tropical Agriculture and Human Resources, Honolulu, Hawaii.
17. Vicente-Chandler, J., H. Irizarry, and S. Silva, 1982. Nutrient uptake by taniers as related to stage of growth and effect of age on yields of the Morada variety. *J. Agric. Univ. P.R.* 66(1):1-10.
18. Young S. and Wu IP, 1981. Proc. XIII Annual Meeting. p. 51-69. Conference Research Extension Series 021, College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii.