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Nutrient Uptake and Dry Matter Production by Intensively Managed Yams Grown In an Ultisol[1, 2]

H. Irizarry and Edmundo Rivera[3]

ABSTRACT

Intensively managed yams grown in a Ultisol and fertilized with 2,240 kg of 10-5-20-3/ha yielded 51.6 T of marketable tubers/ha, containing 18 T of edible dry matter, over an 8-month crop cycle. Uptake of nutrients by the yams was 190, 25, 215, 90 and 35 kg/ha of N, P, K, Ca, and Mg, respectively.

INTRODUCTION

True yams (*Dioscorea* spp.) are an important food crop of the tropics and the third most important root crop grown in Puerto Rico; about 15,500 metric tons with a farm value of $7.6 million. The fleshy tubers provide about 500 cal/100 g of dry pulp and contain 3% protein as well as limited amounts of minerals. Yams can be boiled, baked, or sliced and fried.

Little research has been conducted on the fertilization of yams in Puerto Rico. Gaztambide and Cibes (4) found that the omission of N, P, K, Ca, or Mg from yams growing in sand culture restricted growth, caused deformation of tubers and reduced yields. Abruña et al. (2) and Rodríguez et al. (7) found that acid Ultisols must be limed to at least pH 5.5 for high yam yields.

Sobulo (8) found that *D. rotundata* growing in an unfertilized soil yielded 26.9 T/ha of marketable tubers containing 10,170 kg of dry matter and removed 205, 13, and 112 kg/ha of N, P, and K, respectively, in leaves and tubers over a 9.5-month growing period. Obigbesan and Agboola (6), found that 8-month old tubers of two cultivars of *D. rotundata* yielded 37.9 T/ha of tubers containing 12,165 kg of dry matter and contained 148, 18, 166, 4 and 11 kg/ha of N, P, K, Ca, and Mg, respectively.

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[2] This paper covers work carried out cooperatively between the Agricultural Research Service, USDA, and the Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

[3] Research Horticulturist and Horticulturist, Agricultural Research Service, USDA, Río Piedras PR.

The objective of this study was to determine the monthly and total uptake of N, P, K, Ca, and Mg and also dry matter production by yams that were grown with near optimum fertilization on an Ultisols in the humid region of Puerto Rico.

MATERIALS AND METHODS

The experiment was carried out at the Corozal Substation in a Corozal clay (Aquic Tropudults) with a pH of 4.55 and containing 4 p/m of "available" P (Bray method) and 0.5, 2.3 and 7.5 meq/100 g of soil of exchangeable K, Mg and Ca, respectively.

The field was plowed and harrowed twice and 4.5 T/ha of ground limestone was incorporated into the soil to raise the pH to 5.5. On June 15, 1981 pregerminated tuber sections of cultivar Habanero (*D. rotundata*), each weighing about 200 g, were planted 60 cm apart in ridged rows spaced 90 cm apart. Vines were supported by 2-m long wooden stakes.

Fertilizer rates of 0, 1,120 and 2,240 kg/ha of 10-5-20-3 (N, P_2O_5, K_2O and MgO) were tested arranged in a randomized complete block design with four replications. The fertilizer was applied in two equal amounts, 1 month and 5 months after planting. Plots were 4 × 5 m surrounded by ditches.

Weeds were controlled by a pre-emergence application of 2-(ethylamino)4-(isopropylamino)-6-methylthio-s-triazine (Ametryn)[4] at the rate of 4.5 kg/ha. Afterwards, plots were hand weeded as needed. Immediately after the yams were planted, nematodes and soil insects were controlled with a single band application of 2-methyl-2-(methylthio) propionaldehyde O-methylcarbamoyl oxime (Temik 10G, aldicarb) at the rate of 30 kg/ha. Although the Habanero yam cultivar is highly tolerant to the leaf spot disease caused by (*Colletotrichum* sp.), as a precautionary measure, the foliage was sprayed every 21 days with methyl 1-butylcarbamyol)-2-benzimidazole carbamate) (Benlate, Benomyl) at the rate of 1 kg/ha in 400 liters of water. During dry spells, supplementary irrigation was applied at the rate of 35 mm weekly.

Two months after planting, and every month thereafter, eight plants from each fertilizer treatment were dug up and separated into leaf blades and petioles, vines and tubers. Because Ferguson et al. (3) reported a significant variability in dry matter and nutrient content in different sections of the tubers, only the middle portion was sampled for analysis. Each plant part was weighed and ground, passed through a 20-mesh

[4] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a warranty of materials by the Agricultural Research Service, USDA, and the Agricultural Experiment Station of the University of P.R. or an endorsement over materials not mentioned.

screen, and analyzed for N, P, K, Ca, and Mg. Nitrogen was determined by the Macro Kjeldahl method; P, colorimetrically; K, by flame photometry and Ca and Mg, by the Versenate method after digestion with nitric-perchloric acid.

Eight months after planting, yams were harvested from an area of 2.7 × 3.7 m in each plot from which no plants had been removed and yields of marketable yams determined.

RESULTS AND DISCUSSION

The plants that received the highest level of fertilization (2,240 kg/ha) yielded 51.6 t/ha of marketable tubers, significantly higher at the 5% degree of probability (Duncan's multiple range test) than those produced at the 1,120 kg/ha and 0 fertilizer levels.

The following discussion is, therefore, limited to the results obtained at this highest level of fertilization.

Uptake of N and K increased rapidly with increased age of the plants (fig. 1). Uptake of Ca also increased with age but at a lower rate; Ca uptake decreased after about 5 months of age. Uptake of P and Mg was low at all ages. Uptake of P (not shown in figure 1) was 1.9, 8.4, 20.5 and 25.2 kg/ha at 2, 4, 6 and 8 months after planting, respectively.

Table 1 lists the nutrient content of different parts of the yam plant for N, P, K, Ca and Mg, and also dry matter, as well as the total accumulation of nutrients and dry matter for all the parts. Total accumulation of nutrients was 189, 25, 215, 91 and 36 kg/ha for N, P, K, Ca and Mg, respectively. About 135, 21, 160, 17 and 24 kg/ha of N, P, K, Ca, and Mg, respectively, were removed from the field in the harvested tubers, 18,000 kg/ha of dry matter.

Nutrient content of the leaves and vines increased up to about 6 months (table 2). Nutrient content of the tubers, on the other hand, increased rapidly with age of the plants. The tubers increased steadily in weight from about 3 months after planting until harvest, 8 months later (fig. 2). Dry matter in the leaves and vines peaked at about 6 months after planting.

Total dry matter at harvest was about 21,500 kg/ha, of which 18,000 kg/ha was edible tubers. Yields of fresh marketable tubers was 51.6 t/ha.

The following tabulation compares the relative efficiency of yams with that of taniers, including tubers and corms, as found by Vicente-Chandler et al. (10), and cassava, as reported by Irizarry et al. (5) in terms of the use of NPK, N, and K to produce edible dry matter (DM).

Crop	*NPK:DM*	*N:DM*	*K:DM*
Yams	1:41.9	1:94.7	1:83.7
Taniers	1:30.9	1:73.4	1:57.4
Cassava	1:17.1	1:37.9	1:32.4

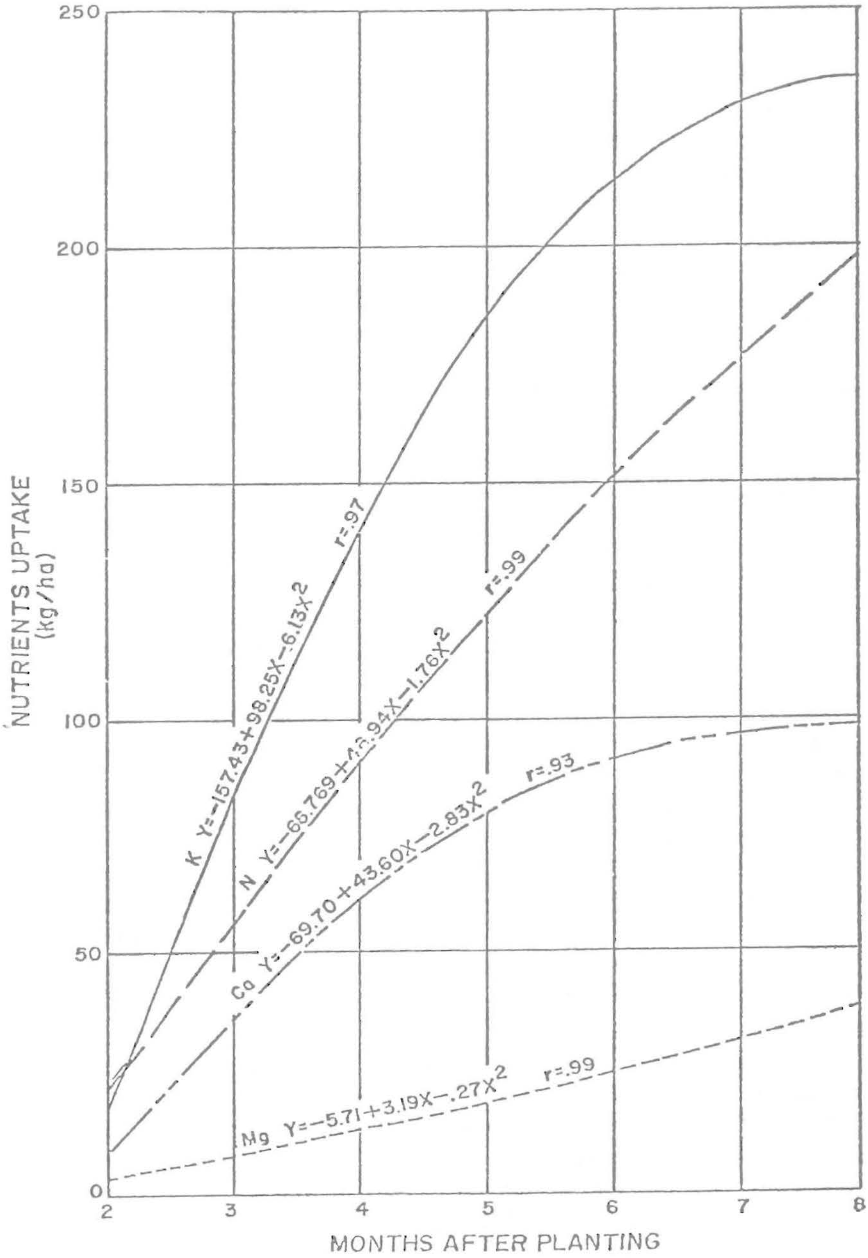

FIG. 1.—Uptake of nutrients by intensively managed yams during an 8-month cropping cycle in a Corozal clay (Ultisol).

Yams were the most efficient and cassava the least in the use of either NPK, N or K to produce edible dry matter.

Total nutrients contained in the yam plants were equivalent to 190, 57, 259 and 58 kg/ha of N, P_2O_5, K_2O and MgO, respectively, as expressed in commercial fertilizer (table 3). Experiments conducted by Abruña et al. (1) and Vicente-Chandler et al. (9) with tropical grasses growing in Ultisols and Oxisols indicated that the nutrient supplying power of these soils is about 80 kg/ha yearly of N and K_2O, and 20 kg/ha yearly of MgO. Only small amounts of residual P are available in these soils because they have no P-bearing minerals. For 8-month crops like yams, these soils could supply about 53 kg/ha of N and K_2O and 13 kg/ha of MgO.

TABLE 1.—*Quantity of nutrients and dry matter in different parts of the yam plant at harvest time (kg/ha)*

Plant part	Nutrient					Dry matter
	N	P	K	Ca	Mg	
Stems	7	1	14	18	2	1,400
Leaves	47	3	41	56	10	2,100
Tubers	135	21	160	17	24	18,000
Total	189	25	215	91	36	21,500

TABLE 2.—*Nutrient content in the various parts of the yam plant at different ages (kg/ha)*

Months after planting	Leaves					Vines					Tubers				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
2	16.1	1.3	17.4	10.0	1.2	4.1	0.4	7.7	3.6	0.5	2.5	0.2	4.1	1.1	0.3
3	48.8	-	54.0	23.5	5.1	7.5	-	17.0	6.6	1.2	3.8	-	5.4	0.9	0.5
4	60.4	3.9	68.7	35.0	5.9	6.3	1.5	12.7	8.6	1.2	16.9	3.0	27.6	0.9	2.7
5	72.8	-	91.6	53.4	7.0	5.7	-	15.8	14.7	1.1	43.0	-	69.7	3.7	8.6
6	67.4	4.2	70.8	64.7	7.8	11.3	1.5	27.6	38.8	3.7	75.3	14.9	133.4	12.4	12.8
7	56.3	-	68.7	62.6	9.7	7.5	-	17.2	18.1	1.7	124.2	-	169.8	14.0	19.2
8	46.6	2.9	40.5	55.9	9.9	6.8	0.6	14.3	17.8	1.7	133.9	21.7	159.2	17.8	24.8

On the basis of total nutrient uptake and the capacity of the soils to supply nutrients, near optimum yields of yams should be obtained by applying 137, 57, 206 and 45 kg/ha of N, P_2O_5, K_2O, and MgO, respectively. However, as reported by Vicente-Chandler et al. (9), about 50% of the N, 20% of the P_2O_5, and 25% of the K_2O and MgO applied as fertilizer are lost. To compensate for these losses yams must be fertilized with 274, 68, 258, and 56 kg/ha of N, P_2O_5, K_2O and MgO, respectively. This is roughly equivalent to about 2,000 kg/ha of a 14-3-13-3 commercial fertilizer.

On the basis of the monthly nutrient uptake by yams the recommended fertilizer should be applied in two equal applications about 2 and 5 months after planting.

Table 1 shows that very limited amounts of N, P and K are returned to the soil in the plant residues of yams which therefore deplete the soil of nutrients more than cassava (5).

Table 4 shows percent nutrient content of the various parts of the yam plant at different stages of growth. At all ages, nutrient concentrations were higher in the leaves than in the other parts of the plant. Contents of N, P, and K showed a downward trend with increasing age, whereas Ca and Mg contents tended to increase with age. In the tubers, however, Ca decreased. These data suggest that the most appropriate time for determining the nutritional status of the yam plant is about 5 months after planting when near maximum growth rates of leaves and vines occur. At this 5-month stage, percentage nutrient content of the leaves was approximately: N = 2.5, P = 0.18, K = 3.0, Ca = 2.0 and Mg = 0.25%.

TABLE 3.—*Computation of the fertilizer required by the yam plant to produce near optimum yields over an 8-month cycle*

Nutrient	Total uptake by the yam plant	Released by the soil	To be supplied from fertilizer	To be applied as commercial fertilizer[1]
		kg/ha		
N	190	53	137	274
P_2O_5	57	0	57	68
K_2O	259	53	206	258
MgO	58	13	45	56

[1] Assuming fertilizer losses of 50% N, 20% P_2O_5 and 25% of K_2O and MgO.

TABLE 4.—*Percent monthly nutrient content in the leaves, vines and tubers of the yam plant*

Age of the plant	Leaves					Vines					Tubers				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Months															
2	2.88	0.24	3.11	1.76	0.20	0.92	0.10	1.66	0.75	0.11	1.23	0.07	1.95	0.55	0.13
3	2.78	–	3.11	1.36	0.29	0.84	–	1.89	0.73	0.13	1.23	–	1.77	0.38	0.20
4	2.60	0.17	2.97	1.51	0.26	0.59	0.15	1.17	0.82	0.11	0.79	0.14	1.26	0.04	0.12
5	2.46	–	3.04	1.82	0.23	0.51	–	1.37	1.31	0.10	0.84	–	1.36	0.07	0.16
6	2.78	0.18	2.98	2.84	0.33	0.60	0.08	1.48	1.32	0.22	0.70	0.14	1.23	0.11	0.12
7	2.20	–	2.66	2.51	0.38	0.58	–	1.35	1.36	0.14	0.94	–	1.24	0.10	0.14
8	2.10	0.13	1.69	2.54	0.42	0.53	0.05	1.11	1.36	0.14	0.81	0.13	0.95	0.10	0.14

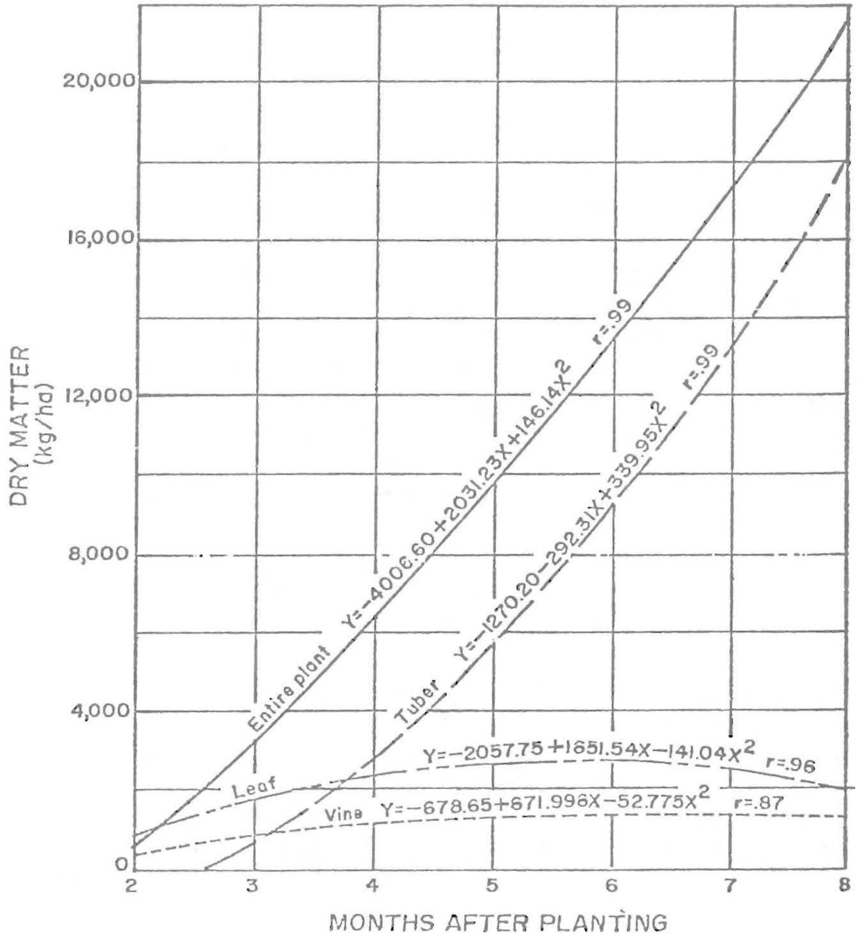

FIG. 2.—Dry matter production by intensively managed yams during an 8-month cropping cycle in a Corozal clay (Ultisol).

These concentrations are very similar to those reported by Obigbesan and Agboola (6) in 6-month-old *D. rotundata* except for Ca content, which was about twice as high, but within the ranges reported by Rodríguez et al. (7) for 6-month-old yams grown on an Ultisols.

RESUMEN

Se midió la extracción mensual y la total de nutrimentos y la producción de materia seca del ñame Habanero, *D. rotundata* en un suelo Corozal arcilloso (Ultisol). Las plantas se abonaron con un análisis 10-5-20-3 (N,

P_2O_5, K_2O y MgO) a razón de 0, 1,120 y 2,240 kg/ha dividido en dos aplicaciones l y 5 meses después de la siembra.

Mensualmente, empezando 2 meses después de la siembra, se arrancaron ocho plantas por tratamiento y se dividieron en láminas y pecíolos, tallos y tubérculos. Se determinaron sus pesos verde y seco y se analizaron para varios nutrimentos.

El abonado con 2,240 kg/ha produjo el mayor rendimiento, 51.6 Tm/ha de tubérculos comerciales en 8 meses. A esa edad, las plantas contenían 190, 25, 215, 90 y 35 kg/ha de nitrógeno, fósforo, potasio, calcio y magnesio, respectivamente.

A mayor longevidad de las plantas, aumentaba la extracción de nitrógeno y potasio, mientras que la del calcio aumentó gradualmente hasta los 6 meses; después disminuyó la tasa de aumento. La extracción de fósforo y magnesio fue baja durante el ciclo de crecimiento.

La materia seca comestible en los tubérculos aumentó rápidamente a partir del tercer mes después de la siembra; se obtuvo, una producción de 18,000 kg/ha a los 8 meses. En las hojas y tallos la materia seca aumentó gradualmente durante los primeros 6 meses, pero luego bajó.

El ñame fue más eficiente que la yuca y la yautía en el uso de nutrimentos según lo indica la proporción en relación a la materia seca comestible producida.

El contenido en nutrimentos fue siempre mayor en las hojas. Un contenido de alrededor de 2.5, 0.18, 3.9, 2.0 y 0.25 % de nitrógeno, fósforo, potasio, calcio y magnesio, respectivamente, a los 5 meses de edad indica un nivel adecuado de abonamiento.

Cálculos basados en la extracción de nutrimentos en el ñame, las cantidades de éstos disponibles en los suelos Ultisol típicos de Puerto Rico y las pérdidas de nutrimentos aplicados como abono, demuestran que para obtener rendimientos óptimos es necesario aplicar alrededor le 274, 68, 258 y 56 kg/ha de N, P_2O_5, K_2O y MgO, respectivamente, equivalentes a 2,000 kg/ha de un abono comercial 14-3-13-3. El abono debe aplicarse en cantidades iguales a los 2 y 5 meses después de la siembra.

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