Tillage and fertilizer rate effects on yam yields (*Dioscorea alata* L.)[1]

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ABSTRACT

In Puerto Rico yam (*Dioscorea* spp.) is usually planted in thoroughly tilled soils of the mountain region. An experiment was established in an Ultisol (aquic tropudults), a Vertisol (udic chromusterts) and an Oxisol tropeptic haplorthox) to study the effect of tillage and fertilizer rates on yield of the Binugas yam (*Dioscorea alata* L.). Three tillage treatments (conventional, deep and minimum) were compared to no-till; and three fertilizer levels (0, 1X and 2X the recommended level) were evaluated. The highest yields were observed in the conventionally tilled plots but differences among tillage treatments were significant only in the Ultisol and Vertisol soils. At these sites, yields under no-tillage were significantly lower than those under conventional tillage. No yield response to tillage was observed in the Oxisol, possibly because of the good physical condition of this soil. Response to fertilizer treatments was observed only in the Oxisol, a soil of low native fertility.

RESUMEN

Efecto de la labranza y el abonamiento en el rendimiento del ñame (*Dioscorea alata* L.)

En Puerto Rico el ñame (*Dioscorea* spp.) usualmente se siembra en terrenos bajo labranza intensiva en la zona montañosa. Se estudió el efecto de la labranza y los niveles de abonamiento en la producción del ñame Binugas (*Dioscorea alata* L.) en tres suelos de diferentes propiedades físicas y químicas: un Ultisol (aquic tropudults), un Vertisol (udic chromusterts) y un Oxisol (tropeptic haplorthox). Se compararon tres tipos de labranza (convencional, profunda y mínima) con la no labranza y tres niveles de abonamiento (0, 1X y 2X el nivel recomendado para este cultivo). Los rendimientos más altos se obtuvieron en las parcelas labradas convencionalmente; las diferencias, sin embargo, fueron significativas sólo en los suelos Ultisol y Vertisol. En éstos los rendimientos de las parcelas sin labranza fueron significativamente menores que en las parcelas labradas convencionalmente. En el suelo Oxisol las diferencias en rendimiento no fueron significativas debido posiblemente a las buenas condiciones físicas

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de ese suelo. Sin embargo, sólo en el Oxisol hubo respuesta a la aplicación de fertilizante. Los análisis de suelo realizados al iniciar el experimento indicaron que la fertilidad del predio era de media a baja.

INTRODUCTION

Yam (*Dioscorea* spp.) is the most important root crop in Puerto Rico. In 1988-89 it contributed 43% of the gross income generated by root crops. For that year, production reached 10,682 tons with a farm gate value exceeding $7.8 million (3). More than 4,075 tons of yam was imported (4), a fact that indicates the need to increase production to satisfy local demand.

Traditionally, yams are planted on poor acid soils of the mountain region. Plowing and harrowing twice followed by bedding is the conventional soil preparation method recommended for yam production in Puerto Rico (5). This practice, however, may be detrimental in erosion-susceptible soils where yams are most often grown. If no-till or minimum tillage could be implemented without affecting yield, the erosion potential in these areas could be diminished. Limited research has been conducted in Puerto Rico concerning tillage methods for yam production. Vicente-Chandler *et al.* (11) obtained yam yields that were as high in undisturbed as in thoroughly-tilled, highly-weathered soils of the mountain region. Similar results were obtained with other root crops (11, 1). Lugo *et al.* (10), however, reported a 75% yield reduction in taniers (*Xanthosoma* spp.) grown on an undisturbed Oxisol.

Some research has been conducted in Puerto Rico concerning fertilization of yams. Irizarry *et al.* (7) found that *D. rotundata* grown on an Ultisol and fertilized with 2,240 kg/ha of 10-5-20-3 fertilizer yielded 51.6 t/ha of marketable tubers. Nutrient uptake over an 8-month crop cycle was 190, 25, 215, 90 and 35 kg/ha of N, P, K, Ca and Mg, respectively. Since under no-tillage conditions soil nutrients may not be as readily available to the plant as under conventional tillage, increased rates of fertilizer might compensate for reductions in yield. Yam cultivars have been introduced for evaluation and identification of high yielding capacity and resistance to anthracnose, a prevalent disease caused by *Colletotrichum gloeosporioides*. Among these, the cultivar Binugas (*Dioscorea alata* L.) is being intensively evaluated. In an experiment comparing five *D. alata* cultivars grown on an Ultisol, Binugas yam was among the higher producers, with an average marketable yield of 41.6 t/ha (6). Under intensive management and without vine support, at the same location, up to 72 t/ha of marketable tubers was obtained (8). This cultivar produces large, rounded or semi-rounded tubers close to the soil surface. This shallow growth habit might minimize yield losses under low-input management. Moreover, tuber size might possibly be reduced under

minimum or no tillage regimes and conform with market acceptability, since in many instances tubers are oversized and off-shaped, resulting in lower prices at the farm gate.

The research here reported was conducted to determine the effect of tillage treatments and fertilizer rates on the yield of Binugas yam at three locations in Puerto Rico.

MATERIALS AND METHODS

The experiment was planted in May 1988 at three ecologically different locations: the Lajas, Isabela and Corozal substations of the UPR Agricultural Experiment Station. At the Lajas substation, in the dry southwest area, the soil series is Fraternidad clay (udic cromusterts, very fine, montmorillonitic isohyperthermic) having a pH of 6.6, and containing 2.6% organic matter, 27.3 mg/kg of available P, and 0.75, 24.5 and 15.6 $cmol_c$/kg of exchangeable K, Ca and Mg, respectively. Mean annual rainfall is 1100 mm. At Corozal, in the humid mountain region, the soil series is Corozal clay (aquic tropudults, clayey, mixed, isohyperthermic) having a pH of 5.3 and containing 4.8% organic matter, 46.5 mg/kg of available P and 1.25, 12.7 and 1.2 $cmol_c$/kg of exchangeable K, Ca and Mg, respectively. Mean annual rainfall is 1650 mm.

The treatments were arranged in a split plot design with four replications at each location. Soil preparation methods comprised the main plots, and fertilizer levels the subplots. For all locations the tillage treatments were 1) No-till (undisturbed); 2) conventional till (disc-plowed and harrowed twice to a depth of 20 to 30 cm and then bedded); 3) deep till (plowed to a depth of over 30 cm); and 4) minimum till (either chiselled to a depth of 20 cm or tilled to a depth of 10 cm with a cultivator). Main plot size was 14 m X 6 m, split into three subplots for fertilizer application. Fertilizer was applied at 0, 1 and 2 times the recommended level (6), which was 274 kg/ha of N 68 kg/ha of P_2O_5 and 258 kg/ha of K_2O. The fertilizer was applied at 2 and 5 months after planting in equal quantities each time.

At Isabela and Corozal, tuber sections of about 115 g, treated with thiabendazole (Mertec), were planted every 46 cm within the row in rows 122 cm apart. At Lajas, the planting distance was 76 cm within and between rows. Weeds were controlled chemically and by hand weeding. Nematodes and soil insects were controlled with a single band application at planting of aldicarb (Temik 10 G) at the rate of 30 kg/ha. The foliage was sprayed with benomyl (Benlate), at the rate of 2 kg/ha for control of anthracnose.

Wire trellises were installed 1.3 m above ground level for vine support. Soil samples were collected before planting for chemical analyses and to determine nematode population. Overhead irrigation was applied

as necessary during the growing season. Yams were harvested December 1988, about 8 months after planting and following senescence and desiccation of the vines.

RESULTS AND DISCUSSION

Yield response to tillage treatments was observed at Corozal and Lajas whereas response to fertilizer levels was observed only at Isabela (table 1). There were no significant interactions between tillage treatments and fertilizer levels; that is, the response to fertilizer was independent of the tillage treatments.

The highest yields were obtained under conventional tillage. The average yields for this tillage treatment were 45,223 kg/ha at Corozal, 20,187 kg/ha at Lajas and 16,227 kg/ha at Isabela. No-tillage resulted in

TABLE 1.—*Yam productivity under variable tillage and fertilization regimes at three locations*

Tillage treatment	Fertilizer level 0	1	2	Mean
		- *kg/ha* -		
		Corozal		
Conventional	39630	53440	42600	45223 a[1]
Deep-till	46440	37640	40690	41590 a
Minimum	22770	27230	25740	25247 b
No-till	3870	10720	13220	9270 b
Mean	28178	32258	30563	
		Lajas		
Conventional	18760	19460	22340	20187 a
Deep-till	17080	14180	23100	18120 ab
Minimum	9780	9730	12240	10583 ab
No-till	5960	9310	9140	8137 b
Mean	12895	13170	16705	
		Isabela		
Conventional	12800	17530	18350	16227
Deep-till	11910	16600	17840	15450
Minimum	11790	16450	12680	13640
No-till	3760	9630	6960	6783
Mean	10065b	15053a	13958a	

[1]Means followed by the same letter do not differ significantly at the P = 0.05 probability level (Duncan's multiple range test).

a significant yield reduction of 80% at Corozal and 60% at Lajas when compared to conventional tillage. Plots with conventional tillage outyielded those with minimum tillage at Corozal, whereas productivity under deep till was similar to that of conventional tillage at all locations (table 1). Yields obtained at Corozal from conventional and deep-plowed treatments were similar to those obtained in other experiments at the same location (6), reasserting the high yielding capacity of this cultivar. There were no significant differences among tillage treatments at Isabela (table 1), even though a 58% yield reduction was recorded for the no-till plots. At this location, tillage did not increase yield significantly, perhaps because of the naturally good physical condition of Coto clay. Yields, however, were relatively low at Isabela, where severe symptoms of anthracnose were observed. The disease could have been a yield limiting factor masking any tillage effect. At Lajas, yields were also low. Because of its high tendency for compaction, Fraternidad clay, the dominant soil series at this location, is not well suited for yam production. The response to tillage observed at Corozal and Lajas suggests that heavier soils require a more efficient tillage preparation to maximize yields.

At the three sites, yields from the 0 fertilizer level were lower than from the 1X level (table 1). Yields of 28,178 kg/ha, 12,895 kg/ha, and 10,065 kg/ha were obtained with no fertilizer at Corozal, Lajas and Isabela, respectively, whereas 32,258 kg/ha, 13,170 kg/ha and 15,053 kg/ha were obtained with the 1X level of fertilizer at the same locations. The response to fertilizer application was significant only at Isabela, where a yield decline of 33% was observed when no fertilizer was applied as compared to the yield at the 1X level. A soil test conducted at the beginning of the study indicated low to medium natural fertility at this site (5.8 mg/kg of P and 0.25 $cmol_c$/kg of exchangeable K), whereas at Lajas and Corozal initial soil analyses indicated high levels of P and exchangeable K. As a general guide to crop response, Bray-P levels below 3 mg/kg are considered very low, 3 to 7 mg/kg low, 7 to 20 mg/kg medium, and above 20 mg/kg adequate to high (9). An exchangeable K value of 0.38 $cmol_c$/kg is frequently considered high enough to ensure adequate K supply for plant growth (2). Increasing the fertilizer level over the recommended amount (1X level) did not increase yields significantly at any of the locations. It is, therefore, concluded that additional fertilization is not a realistic means of increasing yam productivity at these sites.

Tuber mean weight was affected by both fertilizer and tillage treatments but the response varied with locations (table 2). At Corozal and Lajas, mean weight of tubers grown under no-till was significantly lower than under both conventional and deep till (table 2). A mean weight of 1.1 kg was obtained at Corozal under the no-till treatment, whereas 2.17 and 2.21 kg mean weights were obtained under conventional and deep

TABLE 2.—*Mean weight of tubers as affected by four tillage treatments and three fertilizer levels at three locations*

Tillage treatment	Fertilizer level 0	1	2	Mean
		- kg/ha -		
		Corozal		
Conventional	1.90	2.39	2.23	2.17 a[1]
Deep-till	2.72	1.99	1.92	2.21 a
Minimum	1.82	1.67	1.76	1.75 ab
No-till	0.77	1.07	1.45	1.10 b
Mean	1.80	1.78	1.84	
		Lajas		
Conventional	0.73	0.81	0.81	0.78 a
Deep-till	0.79	0.80	0.86	0.82 a
Minimum	0.58	0.82	0.72	0.71 ab
No-till	0.39	0.68	0.77	0.62 b
Mean	0.63_b	0.78_a	0.79_a	
		Isabela		
Conventional	0.63	0.75	0.720	0.70
Deep-till	0.63	0.66	0.64	0.65
Minimum	0.61	0.76	0.66	0.66
No-till	0.40	0.72	0.51	0.54
Mean	0.57b	0.72a	0.62b	

[1]Means followed by the same letter do not differ significantly at the P = 0.05 probability level (Duncan's multiple range test).

tillage, respectively. At Lajas, mean weights were lower; 0.62, 0.78 and 0.82 kg were obtained under no-till, conventional, and deep tillage, respectively. At both sites, marketable weight and number of tubers (data not shown) were lower under no-till; therefore, the decrease in mean weight reflects a *de facto* reduction of yield. Ideally, the objective of reducing mean weight should not be obtained through a reduction in net yield capacity but rather through an increase in the number of marketable tubers having a mean weight of about 1.0 to 1.5 kg.

At Isabela and Lajas, tuber mean weight under the 0 fertilizer level was significantly lower than under the 1X level treatment. Increasing the fertilizer to the 2X level did not increase mean weight but rather did decrease it at Isabela. At Corozal there were no differences due to the fertilizer levels.

Our results indicate that tillage is necessary for growing yams in heavy textured soils like Corozal clay and Fraternidad clay. Deep tillage seems to be the most appropriate tillage treatment since it requires fewer field operations and yields were as good as under conventional tillage. In addition to lower operating costs, the reduced usage of machinery could contribute toward maintaining good physical soil properties. Alternatively, a two-fold increase in fertilizer rate did not increase yields in any of the locations. Therefore, the existing recommended fertilizer rate for yams seems to be adequate.

LITERATURE CITED

1. Abruña, F., E. G. Boneta, J. Vicente-Chandler and S. Silva . 1967. Experiments on tanier production with conservation in Puerto Rico's mountain region. *J. Agric. Univ. P.R.* 51: 167-75.
2. Barber, S. A. 1984. Soil Nutrient Bioavailability. Wiley and Sons, New York.
3. Departamento de Agricultura. Ingreso Bruto Agrícola de Puerto Rico 1988-89 y 1989-90. Oficina de Estadísticas Agrícolas, Santurce, P.R.
4. Departamento de Agricultura. 1989. Boletín Semestral de Estadísticas Agrícolas, enero-junio 1989. Of icina de Estadísticas Agrícolas. Santurce, P.R.
5. Estación Experimental Agrícola. 1984. Conjunto Tecnológico para la Producción de Farináceas. Publicación Num 101 (Revisada), Esta. Exp. Agric. Univ. P.R.
6. González-Vélez, A. y M. A. Santiago-Córdova. 1989. Rendimiento y resistencia a la antracnosis de 5 cultivares de ñame, *Dioscorea rotundata* Poir in Lam. *J. Agric. Univ. P.R.* 73: 381-82.
7. Irizarry, H. and E. Rivera. 1985. Nutrient uptake and dry matter production by intensively managed yams grown in an Ultisol. *J. Agric. Univ. P.R.* 69: 1-10.
8. —— and ——. 1989. Management of the Binugas yam (*Dioscorea alata*) in Puerto Rico. Proc. CFCS, 25 th Meet. (Jul 2-8), Point-a-Pitre, Guadeloupe, French W.I.
9. Jackson, M. L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J.
10. Lugo-Mercado, H. M., J. Badillo-Feliciano and J. López-García. 1978. Effects of soil compaction on tanier yields. *J. Agric. Univ. P.R.* 62: 52-56.
11. Vicente-Chandler, J., R. Caro-Costas and E. Boneta. 1966. High crop yields produced with or without tillage on three typical soils of the humid mountain region of Puerto Rico. *J. Agric. Univ. P.R.* 50: 146-50.