Raised beds and aeration tubing for growing tanier (*Xanthosoma* spp.) in a poorly drained upland Ultisol with a perched water table[1,2]

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J. Agric. Univ. P.R. 94(3-4):225-235 (2010)

ABSTRACT

Tanier (*Xanthosoma* spp.) constitutes an important dietary component with high market demand in Puerto Rico. However, tanier production in Puerto Rico has decreased dramatically in recent decades, largely because of a condition known as dry root rot (mal seco). One of the soil conditions known to enhance dry root rot is poor drainage, particularly when it occurs in sequence with drought periods. We examined tanier growth and yields in a very poorly drained upland Ultisol under three soil management treatments: 1) planting on the flat; 2) planting on ridges; and 3) planting on ridges with perforated tile drain tube placed at the base of the ridges. All treatments included drip irrigation management to prevent drought stress at any crop growth stage. Water table observation pipes were installed to monitor water table fluctuations. Yields of marketable cormels for treatments 1, 2 and 3 were 5.38, 19.94 and 17.61 t/ha, respectively. Yields for the two ridged treatments (with and without tile drainage) were not statistically different at the p = 0.05 level, but both treatments produced yields statistically greater than that of the non-ridged control treatment. Mean water table depth remained within 50 cm of the soil surface during most of the growing season, and on some sampling dates was within 30 cm of the soil surface. Inspection of soil friability by hand at harvest time showed that even 10 months after initial tillage, the soil retained a loose structure with low mechanical impedance. Results indicate that on poorly drained clay soils with good structure, high yields of tanier can be obtained by planting on ridges under drip irrigation, with no additional benefits obtained by installing aeration tubing. The need to monitor water tables on poorly drained upland soils is also indicated.

Key words: *Xanthosoma* spp., drainage, soil management, drip irrigation, aeration tubing

[1]Manuscript submitted to Editorial Board 11 March 2010.

[2]The authors acknowledge the excellent field assistance of Mr Moisés Rodríguez. This material is based on research funds of the Agricultural Experiment Station of the University of Puerto Rico, Project SP-390.

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RESUMEN

Bancos elevados y tubería de aireación para la producción de yautía (*Xanthosoma* spp.) en un Ultisol de la zona montañosa con pobre drenaje y nivel freático temporero

La yautía (*Xanthosoma* spp.) es parte importante de la dieta puertorriqueña, con alto valor en el mercado. Sin embargo, la producción local ha disminuido dramáticamente en décadas recientes, atribuible en parte a una condición de raíz conocida como "mal seco". Dicha condición se acentúa en suelos pobremente drenados, particularmente si ocurren períodos alternos de sequía y exceso de agua. En un suelo Ultisol muy pobremente drenado de la zona montañosa, se evaluaron los rendimientos de yautía bajo tres sistemas de manejo: 1) siembra convencional en suelo sin bancos elevados; 2) siembra en bancos elevados; y 3) siembra en bancos elevados con tubería para aireación en la base de los bancos. Todos los tratamientos incluyeron riego por goteo para evitar estrés hídrico. Se instalaron tubos perforados de PVC para observación de niveles freáticos. Los rendimientos de cormelos mercadeables fueron 5.38, 19.94 y 17.61 t/ha para los tratamientos 1, 2 y 3, respectivamente. Los rendimientos de los dos tratamientos con bancos (con o sin tubería de aireación) fueron iguales estadísticamente (p = 0.05), pero ambos tratamientos produjeron rendimientos estadísticamente mayores que en el tratamiento sin bancos. El nivel freático promedio permaneció a menos de 50 cm desde la superficie durante la mayor parte del desarrollo del cultivo, y en varias fechas de muestreo se encontró a menos de 30 cm desde la superficie. Una inspección manual del suelo al momento de cosecha indicó que el suelo se mantuvo en condición suelta y friable aun 10 meses luego de la labranza inicial. Los resultados de este estudio indican que en suelos pobremente drenados con buena estructura (baja impedancia mecánica) se pueden obtener altos rendimientos de yautía sembrando en bancos elevados bajo riego por goteo, sin necesidad de instalar tubería de aireación. Se documenta también la importancia de medir los niveles freáticos en suelos pobremente drenados de la zona montañosa.

Palabras clave: *Xanthosoma* spp., drenaje, manejo de suelos, riego por goteo, tubería de aireación

INTRODUCTION

Among the major tropical roots and tubers, tanier (*Xanthosoma* spp.) is one of the most susceptible to poor soil physical conditions It is very sensitive to high soil mechanical impedance (Lugo-Mercado et al., 1978) and poor drainage (Silva and Irizarry, 1978), and tends to be severely affected by a pathological condition known as dry root rot, associated with adverse soil moisture regimes (Lugo et al., 1987; Goenaga and Chardón, 1993). In Puerto Rico, as in other areas of the Caribbean, tanier production has dropped dramatically over the past 25 years (Commonwealth Department of Agriculture, 2003), largely because of increased incidence of dry root rot. Yet market demand for the product remains relatively high. This dry root rot negates a potential source of income for small farm operations in the humid upland regions of Puerto Rico, where the crop is traditionally grown.

Field experiments in Puerto Rico have shown that in naturally well drained soils, dry root rot incidence can be consistently controlled at acceptable levels under adequate irrigation and plant nutrition (Lugo et al., 1987; Goenaga and Chardón, 1993; Goenaga, 1994). However, incidence remains high for *Xanthosoma* grown under natural rainfall in poorly drained soils, apparently because of cyclic periods of excessive wetness followed by drought (Lugo et al., 1987). Poorly drained clay soils abound in one of the agricultural regions of Puerto Rico where *Xanthosoma* has traditionally been grown, namely an east-west belt of gently rolling landscapes between the northern karst belt and the volcanic uplands to the south. This belt roughly comprises the municipalities of Corozal, Ciales, Morovis, Lares, San Sebastián and Moca (Soil Survey Staff, 1982). The gentle topography, combined with deep soils and high rainfall, makes the area one of the most agriculturally productive of the Island. However, impermeable subsoils underlie many of the soils, thus causing seasonal water-logging during rainy seasons and high soil mechanical impedance during dry seasons. Our own preliminary observations at Corozal have indicated that perched water tables may persist for significant time after heavy rainfall events. However, actual water table measurements on these soils have not been documented in the literature.

Lugo et al. (1987) found that tanier yields in poorly drained Corozal clay could be improved by planting on raised beds and maintaining adequate moisture through drip irrigation.Additionally, it has been found that placing porous aeration tubes at the base of raised beds above the water table significantly increased the yields of crops such as carrots and sweet potatoes in poorly drained soils (Islam et al., 1997, 1998).

Following up on these observations, we established an experiment to compare tanier yields in a very poorly drained upland soil under the following treatments: 1) planting on the flat; 2) planting on ridges; and 3) planting on ridges with tile drains placed under the ridge. A secondary objective was to document variations in water table depth throughout the growing season.

MATERIALS AND METHODS

Crop management and harvesting procedures

A field experiment was established in a Corozal clay soil, with approximately 5 to 10% slope located at the Corozal substation of UPR-AES. The Corozal series is classified as a very fine, parasesquic, isohyperthermic Typic Hapludult (Beinroth et al., 2002). The area chosen for the experiment was notorious for wet soil conditions which limited its use for crop production. On 31 March 2005, a *Xanthosoma* crop (cultivar Estela) was established with three management treatments: 1) planting on flat ground (no ridges); 2) planting on ridges; and 3) planting on ridges with aeration tubing under the center of the ridge. The treatments were replicated four times using a randomized complete block design. Ridging and planting were effected in rows on the contour. Each treatment plot consisted of four rows of *Xanthosoma* which were 6.1 m long, with the two middle rows harvested as data. Plant spacing was 30 cm (1 ft) down the row, and row spacing was 1.5 m (5 ft).

After soil tillage, each ridge was constructed by making three consecutive passes with a gang of disks angled toward the center (Figure 1, center). This system allowed constructing ridges which were sufficiently high (on the order of 50 cm) yet wide enough to allow gentle slopes and a fairly wide "plateau" on the top. The wide plateau area provided space for lateral growth of roots and cormels, and the gentle ridge slopes (< angle of repose of the soil) provided long-term stability to the ridges. Previous observations indicated that high narrow ridges constructed with listers tended to collapse only a few months after ridging, much before taniers were ready for harvest. In ridged plots with aeration tubing, the tubing was first installed in a shallow depression dug with a tine implement, followed by ridging soil on top of the tube. Care was taken to ensure that the ends of the tubing were unobstructed so as to allow free air exchange with the atmosphere. Figure 1 shows the location of tile drains and the procedure for constructing ridges; Figure 2 shows elevation of the ridges relative to that of a control plot with no ridges, approximately six months after planting.

A single drip irrigation line was placed alongside each row of tanier, and irrigation was applied once or twice weekly depending on rainfall conditions. The crop was planted in the form of cormel sections weighing approximately 112 g, previously treated for 10 min in a fungicide

FIGURE 1. Field operations for installing tile drain and constructing ridges. Left: installation of tile drain at bottom of tilled plow layer. Center: construction of ridges over tile drain. Right: completed ridges.

FIGURE 2. Persistent ridge height (right) compared to non-ridged ground (left) at six months after planting. The great difference in tanier growth is evident. PVC water table monitoring pipes may be seen in the foreground.

solution of 1 ml of Fludiox[6] in 15 L of water. At two and five months after planting, 112 g of 14-3-13-3 fertilizer was banded around each plant. Weed control practices were as specified by Agricultural Experiment Station Staff (1997).

Perforated PVC pipes of 5 cm nominal diameter were installed to a depth of 1 m in the soil, along two transects oriented downhill on opposite sides of the experimental area. Five pipes were installed along each transect. Depth from the soil surface to the water table was monitored at approximately two-week intervals, by lowering a float (tin can) attached to a measuring rod into each perforated pipe. Two of these water table observation pipes are shown in Figure 2.

Crop harvesting procedure

Plots were harvested at 255 days after planting. One week prior to harvest, four plants from border rows in each plot were destructively sampled for total above-ground biomass (leaves and petioles) and total below-ground biomass (corms, cormels and roots). The plant material was oven-dried for 48 hours at 75° C and weighed. One week later, cormels from all plants in the two middle rows of each plot were harvested. Cormels were partitioned into marketable and non-marketable groups, and each group was weighed separately. Cormels weighing more than 112 g were considered marketable.

[6]Company and trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

Additional measurements

Prior to ridging and planting, soil test samples were taken from the 0 to 15 cm depth interval at four locations of the experimental site, and analyzed for pH in 1:2 soil:water suspensions, exchangeable cations by 1 N ammonium-acetate extraction, organic matter by the Walkley Black wet combustion method, and extractable P by the Bra y II extraction method. Testing was performed by the Central Analytical Laboratory at the Río Piedras Research Center of the UPR Agricultural Experiment Station, as described by the Central Analytical Laboratory Staff (1990).

Aggregate stability analysis was performed on the same samples by wet sieving. A 30-g sample of air-dried aggregates ranging from 2 to 4 mm in diameter was placed on a 2-mm sieve, wetted rapidly by capillarity for 15 minutes, and then the sieve was oscillated up and down under water, by a 2.5 cm stroke at a rate of 60 strokes per minute. The amount of soil remaining in the sieve w as oven dried and weighed. Aggregate stability was quantified as the percentage by mass of the original sample remaining in the sieve.

RESULTS AND DISCUSSION

Soil properties

Results of soil chemical analyses and aggregate stability are given in Table 1. Soil pH and exchangeable K and Ca were at levels normally considered adequate for crop growth (O. Muñiz, Retired Soils Specialist, Agricultural Extension Service, University of Puerto Rico, Mayagüez Campus, personal communication). The only sub-optimal c hemical parameters were exchangeable Mg (optimum >300 mg/kg) and extractable P (optimum > 40 mg/kg). Aggregate stability was high, at approximately 50 percent, a finding which is not unexpected, given the soil organic matter content of nearly 3%. Consistent with the high aggregate stability values , simple manual inspection at harvest indicated that the tilled soil remained soft and friable throughout the growth period of *Xanthosoma*.

TABLE 1.—*Soil properties of experimental plot, Corozal, P.R.*

Soil Property	pH	P	K	Ca	Mg	Soil organic matter	Aggregate stability
		mg/kg	mg/kg	mg/kg	mg/kg	%	%
Mean[1]	6.44	6	439	4,307	127	2.95	51.2
Std. dev.	±0.62	±3	±54	±1,312	±21	±0.50	±6.0

[1]Mean of four observations.

Tanier yields

Yields of marketable and non-marketable cormels for the different treatments are summarized in Table 2. Mean yields of marketable cormels were 19.9, 17.7 and 5.4 t/ha for the ridge , ridge plus aeration tubing, and flat planting, respectively. Plots with ridges yielded slightly higher than plots with ridges and aeration tubing , but the difference was not statistically significant at the p = 0.05 levelHowever, yields for the ridged treatments (with or without aeration tubing) were significantly higher than yields for planting on the flatIt is worth noting that yields in the ridged treatments were on the order of 20 t/ha, which is considered an excellent tanier yield even for well-drained soils.

Comparison of above-ground and below-ground biomass, on an oven-dry per plant basis , is shown for the different treatments in Table 3. Above-ground biomass was significantly different among all three treatments, increasing in the order of control, ridge + tile drain, and ridges only. Below-ground biomass tended to increase in the same order, but

TABLE 2.—*Tanier yield data for different soil management practices.*

		Marketable Cormels		Non-Marketable Cormels	
	No. harvested plants	Means	Standard Error (±)	Means	Standard Error (±)
Treatments	Plants/ha	t/ha			
Control	21,519	5.38 a[1]	3.30	1.84 a	0.91
Ridge	26,898	19.94 b	2.95	1.49 a	0.11
Ridge+Tile drain	26,898	17.61 b	6.72	1.57 a	0.14

[1]Values with the same letter are not statistically different by Fisher LSD (p ≤ 0.05).

TABLE 3.—*Comparison of above-ground and below-ground biomass (oven-dry basis) f or different soil management practices . The first number in eac h cell indicates the mean of f our replicates, and the second number is the corresponding standard deviation.*

	Above-ground biomass (a)	Below-ground biomass (b)	
Treatment	(g/plant)		Ratio (a/b)
Control	82 ± 79 a[1]	465 ± 442 a	0.19 ± 0.07 a
Ridge	237 ± 56 b	1,092 ± 120 b	0.22 ± 0.06 a
Ridge + tile drain	156 ± 100 c	785 ± 364 ab	0.19 ± 0.04 a

[1]Values with the same letter are not statistically different by Fisher LSD (p ≤ 0.05).

the difference between treatments w as significant only between the control plots and plots with ridges onlyThe ratio of above-ground to below-ground biomass was statistically the same for all treatments . Observation of tanier root systems at harvest showed much more vigorous and disease-free root growth in ridged treatments than for planting on the flat (Figure 3).

The number of green (non-senescent) lea ves of the tanier crop w as still significant at time of harvest.Normally this finding would indicate the need for more crop growth time to maximize transfer of above-ground biomass to cormels. However, because buds on the cormels were beginning to germinate, we considered it necessary to harvest immediately to maintain harvest quality. The tendency for premature bud germination in the high-yielding Estela variety has been noted previously (A. Bosque, Agricultural Experiment Station, Isabela, Puerto Rico, personal communication). This finding suggests that greater yields might be obtained if cormel budding could somehow be suppressed until leaf senescence has finalized.

Water table fluctuations throughout the growing season

Water table fluctuations during the growing season are shown in Figure 4. The water table depth occurred within 50 cm of the soil sur - face during most of the growing season and on many sampling dates was within 30 cm of the soil surface. This result indicates that even in sloping upland Ultisols, which are often assumed to be well drained, seasonally high water tables may be a significant yield-limiting factor which should not be ruled out.

FIGURE 3. Tanier root systems at harvest for ridged planting (right) and for planting on the flat (left).

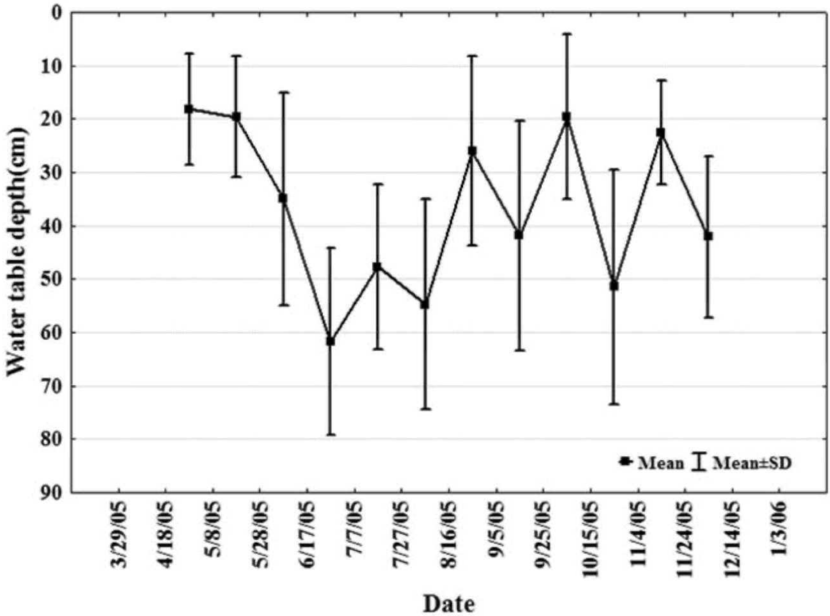

FIGURE 4. Water table fluctuation during the growing season.

In Figure 5, monthly rainfall data for the year 2005 (year of this experiment) are compared to the mean monthly rainfall and standard deviations corresponding to the 10-year period from 1997 to 2007. It can be noted that rainfall during most months of 2005 w as considerably higher than the 10-year average, often exceeding the average by more than one standard deviation. Therefore, results obtained in this experiment can be safely attributed to an exceptionally wet year.

DISCUSSION AND CONCLUSIONS

The results of our study indicate that in well structured soils high tanier yields can be obtained, even under very poorly drained conditions, by planting on high stable ridges with drip irrigation. Cormel yields on ridges were approximately four times the yields obtained on non-ridged plots. Ridged plots with no tile drainage tended to yield higher than ridged plots with tile drainage; however, this difference was statistically significant only for yield of above-ground biomass, not of cormel yields. The economic significance of these results is that, at least in soils similar to the Corozal series, the added expense of installing aeration tubing under ridges is not necessary.

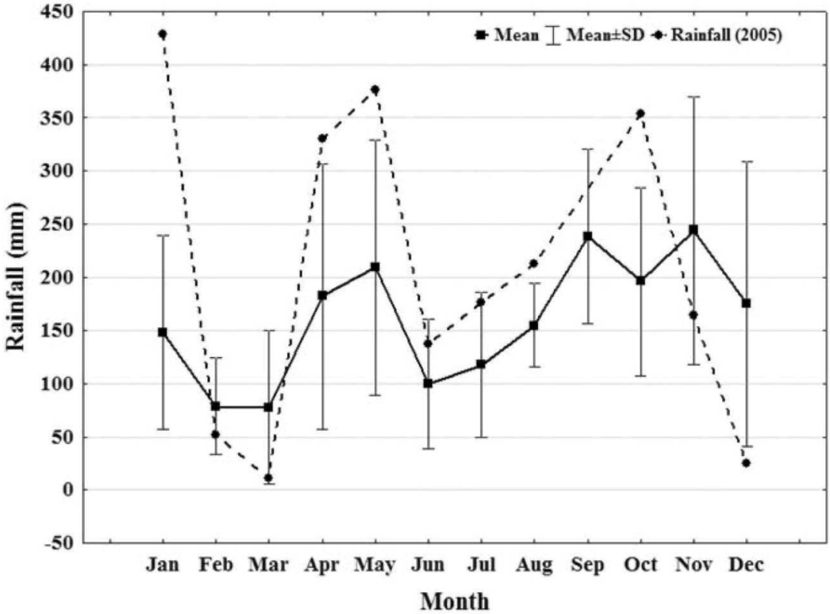

FIGURE 5. Monthly rainfall data for Corozal during year 2005,compared to monthly means and standard deviations for the 10-year period 1997-2007.

Simple inspection by manual crushing of soil indicated that even by harvest time, the soil retained a loose, friable condition. Therefore, excessive mechanical impedance did not appear to be a yield-limiting factor in this study. Lugo et al. (1978) showed that tanier yields can be severely depressed by high soil mechanical impedance.

This study has also documented that yield-limiting perched water tables can occur even in deep sloping soils in humid upland regions, particularly in soils such as Corozal clay with impermeable subsoils. We recommend that productivity evaluations of such soils should include water table monitoring, which is an easily implemented practice requiring no expensive equipment. All that is required is inserting a perforated pipe to a depth below the water table, and determining water table elevation by means of a measuring rod connected to a flotation device.

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