Experiments on Plantain Production with Conservation in the Mountain Region of Puerto Rico[1]

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INTRODUCTION

Plantains (*Musa paradisiaca*), a cooking banana widely used throughout the Tropics, are generally grown on steep lands in the Humid Mountain Region of Puerto Rico where erosion is a serious problem.

Severe mechanical erosion caused by plowing these steep slopes[3] could be prevented on the porous latosols of this Region by planting directly in the sod, and erosion controlled further by maintaining a grass strip between rows of plantains.

The studies discussed in this paper were aimed at evaluating such a system of sod-planting, followed by strip cultivation, in terms of plantain yields, and at determining desirable plant population, and fertilizer and liming practices to use with it.

MATERIALS AND METHODS

The experiments were carried out at Orocovis where the mean annual temperature is about 75° F., with seasonal variations of about 10° F. Highest daily temperatures rarely exceed 85° F. or fall below 65° F. Rainfall is fairly well distributed, averaging about 5 inches monthly.

The soil is Catalina clay, a deep latosol typical of the Humid Mountain Region. Clay minerals are primarily kaolinitic with high free iron oxide content. Analysis of numerous soil samples from the experimental area show an average organic-matter content of 4.1 percent, a pH of 4.8, and 16 m.e. of exchange capacity with 7 m.e. of exchangeable bases per 100 gm. of soil. The upper foot of soil contained 0.20 percent of total nitrogen, 389 pounds of exchangeable potassium, 1,948 pounds of exchangeable calcium, 232 pounds of exchangeable magnesium, and less than 40 pounds of dilute acid-soluble phosphorus per acre. The excellent physical condition of this soil is evidenced by a volume weight of 0.94 with 12 percent of the soil pores

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[3] Vicente-Chandler, J., and Smith, R. M., Principles and practices of bench terracing in Puerto Rico, *J. Soil & Water Conserv.* 6 (3) 134–45.

drained at a tension of 3 atmospheres and a saturated percolation rate of more than 3 inches per hour.

Corms of the Maricongo plantain variety used as seed were cleaned and immersed in boiling water for 1 minute to kill nematodes, and in aldrin solution to kill stem borers. The planting holes and surrounding soil was sprayed with aldrin solution before planting and every 4 months thereafter. The trees were sprayed about every 3 weeks with oil to control leaf spot. These practices controlled insect pests and diseases, but considerable damage by nematodes was noted. Strong winds (40 to 50 m.p.h.) about 1 year after planting caused considerable damage and loss of trees.

In all experiments the limestone and phosphorus as 20-percent superphosphate were applied at planting, all the phosphorus and half the limestone being placed in the planting holes. The magnesium as magnesium sulfate was applied 1 month later, while the nitrogen as ammonium sulfate, and potassium as potassium chloride were applied in equal applications 1, 5, and 9 months after planting, distributed in a circular band 2 feet wide starting 1 to 2 feet from the base of the trees.

In experiments 1 and 2 fertilizer was eliminated as a possible factor affecting yields by applying a total of 4 tons of limestone, 200 pounds of P_2O_5, 100 pounds of magnesium, 400 pounds of nitrogen, and 800 pounds of potassium per acre to all plots.

Diameter of the trees 18 inches from the ground was determined 7 and 12 months after planting. All bunches were weighed and the number of fruits determined.

EXPERIMENT 1

Experiment 1 was designed to test sod-planting and strip cultivation *vs.* complete land preparation and clean cultivation.

Thorough working the soil to a depth of 8 inches, followed by clean cultivation, was compared to planting directly in undisturbed soil following close grazing of the sod and a heavy application of a contact herbicide, pentachlorophenol and oil. The rows were kept free of weeds but volunteer grasses were allowed to grow between rows (figs. 1 and 2). These were kept under control by periodic applications of the contact herbicide. After about 8 months all plots were essentially free of weeds (fig. 1) due to shading and the cumulative effects of weed-control measures.

The treatments were replicated six times in a randomized block design with plots of 12 trees 5 feet apart in two rows 10 feet apart.

EXPERIMENT 2

Experiment 2 was designed to test the effect of plant population with sod-planting and strip cultivation.

Populations of 500 (standard practice), 800, and 1,300 plants per acre were compared.

Treatments were replicated six times in a randomized block design. Plots consisted of 40-foot rows with 5, 8, and 13 trees per plot, respectively. Rows were 10 feet apart.

EXPERIMENT 3

Experiment 3 was designed to test the effect of fertilization and liming with sod-planting and strip cultivation.

FIG. 1.—Ten-month-old sod-planted, strip-cultivated plantains. Grass in strips is being shaded out by the vigorous, closely planted plantains. About 8 tons of fruit, yielding 5 tons of pulp equivalent in feeding value to potatoes, were produced per acre.

Treatments consisted of two levels each of lime, nitrogen, phosphorus, and magnesium, and four levels of potassium, each varied in the presence of a high level of the other nutrients.

The nine treatments were replicated five times in a randomized design with plots of six trees 5 feet apart in a row, and 15 feet between rows. The outer two trees in each plot served as buffers between treatments.

Two fruits from each bunch were separated into skin and pulp, dried, composited by plots, and analyzed for calcium, phosphorus, potassium, and crude protein (N × 6.25).

A strip from the central section of the lamina of the third oldest leaf of the middle four trees of each plot was taken 7 months after planting, dried, and analyzed for nitrogen, phosphorus, calcium, potassium, and magnesium.

A

B

FIG. 2.—Response to nitrogen (A) and phosphorus (B) of plantains receiving all other nutrients in abundance. Plots in foreground received no nitrogen or no phosphorus, while those in background received 200 pounds per acre of nitrogen or P_2O_5, respectively. Note system of planting directly in the sod with a grass strip between rows for erosion control.

RESULTS

SOD PLANTING AND STRIP CULTIVATION *VS.* COMPLETE LAND PREPARATION AND CLEAN CULTIVATION

Table 1 shows that there were no significant differences between methods of land preparation in yields, bunch and fruit size, or percentage of trees bearing a crop. About 8 tons, or 25,000 fruits weighing an average of 0.64 pounds, were harvested per acre. The bunches weighed an average of 28.5 pounds with 45 fruits per bunch.

The sod-planted, strip-cultivated trees were significantly smaller (4.2 *vs.* 5.1 inches in diameter) at 7 months, probably due to competition of the grass strips for moisture during the relatively dry months following planting. This difference in growth had disappeared at 12 months.

TABLE 1.—*Effect of complete land preparation and clean cultivation compared to sod-planting and strip cultivation on growth and yields of intensively managed plantains growing on a latosol (Catalina clay)*

Item		Sod-planting and strip cultivation	Complete land preparation and clean cultivation	L.S.D. 0.05
Fruit per acre	pounds	15,232	17,460	N.S.
Fruit per acre	number	24,480	26,460	N.S.
Weight of bunch	pounds	28.0	29.1	N.S.
Fruit per bunch	number	45.3	44.1	N.S.
Weight of fruit	pounds	.62	.66	N.S.
Trees bearing a crop	percent	68	75	N.S.
Tree diameter at 7 months	inches	4.2	5.1	.64
Tree diameter at 12 months	do.	7.1	7.3	N.S.

EFFECT OF PLANT POPULATION WITH SOD-PLANTING AND STRIP CULTIVATION

Table 2 shows that yields were significantly increased by 8,184 pounds, or 12,584 fruits per acre, by increasing population from 500, standard practice, to 800 plants per acre. Bunch and fruit size were not affected by this increase in population nor was tree diameter or percentage of trees bearing a crop.

Increasing the population to 1,300 trees per acre did not further increase yields. Bunch size and percentage of trees bearing a crop were decreased significantly by such close planting but fruit size was not affected.

EFFECT OF FERTILIZATION AND LIMING WITH SOD-PLANTING AND STRIP CULTIVATION

Table 3 shows that the plantains responded strongly to nitrogen and phosphorus fertilization. Yields were increased by 6,480 pounds or 12,356 fruit per acre when 200 pounds of nitrogen were applied in three applications (treatments 6 *vs.* 2), and by 7,416 pounds, or 12,252 fruits, when 200 pounds of phosphoric acid were applied in the holes at planting (treatments 5 *vs.* 2).

TABLE 2.—*Effect of plant population on growth and yields of sod-planted, strip-cultivated plantains*

Item		500 trees per acre (10′ × 8′)	800 trees per acre (10′ × 5′)	1,300 trees per acre (10′ × 3′)	L.S.D. (0.05)	L.S.D. (0.01)
Fruit per acre	pounds	10,926	19,110	17,351	3,750	5,200
Fruit per acre	number	17,966	30,550	28,106	7,780	10,770
Weight of bunch	pounds	28.3	29.4	24.2	3.5	4.8
Fruit per bunch	number	46.7	47.0	39.2	4.1	5.7
Weight of fruit	pounds	.61	.63	.62	N.S.	—
Trees bearing a crop	percent	77	81	55	18.6	25.7
Tree diameter at 7 months	inches	4.6	4.6	4.5	N.S.	
Tree diameter at 12 months	do.	7.3	7.0	6.8	N.S.	

TABLE 3.—*Effect of fertilization on growth and yields of intensively managed plantains planted directly in the sod, followed by strip cultivation*

No.	Fertilization (per acre) Ca	N	P_2O_5	K	Mg	Fruits per acre	Fruits per acre	Average weight of bunch	Average fruits per bunch	Trees bearing a crop	Tree diameter at 7 months	Tree diameter at 12 months
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Number*	*Lb.*	*Number*	*Percent*	*Inches*	*Inches*
1	0	0	0	0	0	12,656	20,664	22.6	36.9	70	2.6	5.6
2	8,000	200	200	400	500	19,428	32,324	26.9	44.7	90	4.2	6.6
3	0	200	200	400	500	20,856	36,100	27.6	47.6	95	4.5	6.7
4	8,000	200	200	400	0	17,612	27,644	29.3	45.7	75	4.2	6.8
5	8,000	200	0	400	500	12,012	20,072	23.1	38.6	65	3.2	6.2
6	8,000	0	200	400	500	12,948	19,968	24.9	38.4	65	3.0	5.9
7	8,000	200	200	0	500	16,500	25,140	27.5	41.9	75	3.9	6.7
8	8,000	200	200	200	500	19,304	30,660	28.4	45.4	85	4.2	6.9
9	8,000	200	200	800	500	21,904	34,264	30.9	48.7	90	4.3	6.8
L.S.D. 0.05						5,740	9,300	5.05	8.61	21.4	0.80	.56
L.S.D. 0.01						7,700	12,480	6.78	9.53	28.6	1.08	.76

Significantly fewer trees (65 *vs.* 90 percent) produced a bunch in the no-nitrogen and no-phosphorus plots. Response of the plantains to both nitrogen and phosphorus was also evidenced by significant differences in growth at 7 months, the effect of nitrogen still being apparent at 12 months.

The plantains did not respond in growth or yield to applications of lime, magnesium, or potassium.

Table 4 shows that leaf composition at 7 months, when all the phosphorus, lime, and magnesium, and two-thirds of the nitrogen and potassium had been applied, reflected the later response in yields to nitrogen and phosphorus applications. Leaves from the no-nitrogen plots averaged 2.79 percent nitrogen compared to 3.86 percent in leaves from plots receiving 200 pounds of nitrogen per acre, while leaves from the no-phosphorus plots had only 0.13 percent of phosphorus as compared to 0.18 percent for leaves from the plots receiving 200 pounds of P_2O_5.

TABLE 4.—*Percentage dry-weight composition of plantain leaves 7 months after planting, as affected by fertilization with nitrogen, phosphorus, potassium, calcium, and magnesium*

No.	Fertilization per acre					Nitrogen 7 mo.	Phosphorus 7 mo.	Calcium 7 mo.	Magnesium 7 mo.	Potassium 7 mo.
	Ca	N	P_2O_5	K	Mg					
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	0	0	0	0	0	3.23	0.16	0.61	0.17	3.52
2	8,000	200	200	400	500	3.86	.18	.62	.26	3.65
3	0	200	200	400	500	4.04	.16	.63	.31	3.37
4	8,000	200	200	400	0	4.18	.15	.69	.24	3.34
5	8,000	200	0	400	500	4.38	.13	.60	.26	3.34
6	8,000	0	200	400	500	2.79	.17	.64	.25	3.57
7	8,000	200	200	0	500	4.20	.17	.69	.31	2.77
8	8,000	200	200	200	500	4.01	.18	.58	.31	3.26
9	8,000	200	200	800	500	3.79	.16	.57	.27	3.72
L.S.D. 0.05						1.07	0.025	N.S.	0.06	0.54
L.S.D. 0.01						1.43	.033	N.S.	.08	.73

On the other hand, magnesium and calcium applications did not affect leaf content of these nutrients, indicating a sufficiency of these nutrients and presaging the lack of response to their application.

Although the lack of a response to applications of potassium shows that sufficient potassium was available in the soil, fertilization with this nutrient increased the content in the leaves.

Applications of the various nutrients had no significant effect on content of the other nutrients in the leaves, although the average magnesium content increased from 0.26 percent (treatment 2) to 0.31 percent when either calcium (treatment 3) or potassium (treatment 7) were not applied.

Table 5 shows that the skins contained much more calcium, nitrogen, phosphorus, and potassium than the pulp, which was very low in minerals.

Calcium, phosphorus, and potassium fertilization had no marked effect on content of these nutrients in the fruit, but nitrogen fertilization slightly, but significantly, increased the crude-protein content of both skin and pulp.

The following tabulation shows the proportion of pulp and skin in 100 pounds of fruit:

Part	*Green weight (pounds)*	*Dry matter (percent)*	*Dry weight (pounds)*
Pulp	64.3	38.8	24.9
Skin	35.7	14.1	5.0

About 83 percent of the dry matter of plantains is composed of highly nutritive pulp comparable in caloric value to corn.

TABLE 5.—*Effect of fertilization with nitrogen, phosphorus, potassium, and lime on percentage dry-weight content of these nutrients in the fruit of plantains*

Calcium			Crude protein			Phosphorus			Potassium		
$CaCO_3$ applied per acre	Pulp	Skin	N applied per acre	Pulp	Skin	P_2O_5, applied per acre	Pulp	Skin	K applied per acre	Pulp	Skin
Pounds	*Percent*	*Percent*	*Pounnds*	*Percent*	*Percent*	*Pounds*	*Percent*	*Percent*	*Pounds*	*Percent*	*Percent*
0	0.02	0.13	0	2.63	6.88	0	0.07	0.10	0	1.21	4.64
8,000	.02	.13	200	2.81	7.94	200	.07	.11	200	1.34	4.84
									400	1.30	4.67
									800	1.35	4.85

DISCUSSION

Utilization of the steep, humid mountain lands of Puerto Rico with their tremendous productive capacity arising from year-round warm weather, high rainfall, and deep friable soils, is limited by two major difficulties: The virtual impossibility of mechanization and the need for erosion control.

The experiments discussed above clearly show that the porous latosols of this Region do not require plowing for plantains and probably other bananas, thus decreasing the need for mechanization, preventing mechanical erosion caused by plowing, and reducing planting costs. They also show that a strip of grass, periodically mowed or treated with contact herbicides, can be maintained between rows further to control erosion without reducing plantain yields, if fertilization is adequate.

Thus, with plantains and bananas at least, the major difficulties in utilization of the steep, humid mountain lands can be largely surmounted by using such a system of sod-planting and strip cultivation.

Tremendously high yields of food can be produced on these steep lands by intensively managed plantains grown in this manner. Of the 8 tons or so of fruit produced per acre, 5 tons are edible pulp comparable in feeding value to potatoes, and containing 2 tons of dry matter, with a caloric content similar to that of corn. Much higher yields will become possible as improved practices, particularly for nematode control, are developed. If necessary, the entire caloric requirements of Puerto Rico's inhabitants, now supplied mostly by imported rice, could be produced on about 400,000 acres of steep mountain lands. In addition, the skins and underground corms of plantains can be of value for feeding livestock.

Although plantains in Puerto Rico usually produce only one good crop, the authors have observed that, with intensive management, including a complete program of pest control, ratoon production of several excellent crops in succession is possible without replanting.

The response of plantains to phosphorus fertilization on this soil with less than 40 pounds of dilute acid-soluble phosphorus per acre is to be expected. Application of phosphorus in the hole at planting seems a desirable practice to reduce fixation by these acid soils high in free iron oxides. It also provides a supply of this nutrient, which moves very little into the soil, at a depth where moisture is usually abundant, so the phosphorus can be utilized by the plant as required.

Although the soil had a high nitrogen content this was largely in organic forms unavailable to plants, hence the strong response to nitrogen fertilizer.

The exchangeable calcium and magnesium content of the soil was obviously sufficient to meet the requirements of plantains.

The lack of response to potassium, which is taken up by plantains in much larger quantities, estimated at 250 pounds per acre, than any other nutrient, was a surprise, although the soil contained considerable exchangeable potassium. On soils with less available potassium a strong response to applications of this nutrient is likely.

It would seem that soils containing more than about 400 pounds of exchangeable potassium, or 250 pounds of exchangeable magnesium per acre in the upper foot, do not require fertilization with these nutrients, at least for the first crop of plantains. On the other hand, nitrogen fertilization is required even on soils high in total nitrogen, while soils with less than 40 pounds of acid-soluble phosphorus also appear to require heavy applications of this nutrient.

A leaf content at 7 months of about 2.8 percent of nitrogen or less, or of 0.13 percent of phosphorus or less, indicates a deficiency of these nutrients and a response to their application as fertilizer should follow. On the other hand, a calcium content of about 0.60 percent, a magnesium content of 0.24 percent, or a potassium content of 2.8 percent, indicates that the supply of these nutrients is adequate for the production of high yields of plantains.

SUMMARY

Just as high yields and quality of plantains, a cooking banana widely used throughout the Tropics, were produced by planting directly in the sod, followed by strip cultivation for erosion control, as after complete land preparation and clean cultivation on a typical latosol in the Humid Mountain Region of Puerto Rico.

The effects of plant population and of fertilization with sod-planting and strip cultivation were studied.

Increasing the number of trees from 500, which is standard practice, to 800 per acre increased yields by 4 tons of fruit. No further increase resulted from increasing the population to 1,300 trees per acre.

Plantains responded strongly in yield to applications of 200 pounds of nitrogen and of phosphoric acid per acre on this soil, which contained 0.20 percent of nitrogen and less than 40 pounds of dilute acid-soluble phosphorus per acre. No response to lime, magnesium, or potassium was evident on this soil which had a high content of these nutrients in available form.

The nitrogen, phosphorus, and potassium contents of the plantain leaves increased with applications of these nutrients as fertilizer, but applications of magnesium and calcium did not affect the content of these nutrients in the leaves. Leaf contents of 2.8 percent of nitrogen, or 0.13 percent of phosphorus, indicated a deficiency of these nutrients, while a calcium content of 0.60, a magnesium content of 0.24, and a potassium content of 2.8 percent indicated a sufficiency.

The experiments showed that 8 tons of plantains yielding 5 tons of edible pulp comparable in feeding value to potatoes, or 2 tons of dry matter with a caloric content similar to that of corn, can be produced per acre with excellent erosion control on steep lands in the Humid Mountain Region of Puerto Rico.

RESUMEN

El rendimiento y la calidad de los plátanos, sembrados en un suelo latosol de la región húmeda montañosa de Puerto Rico, fueron similares cuando se proveyó una preparación completa del terreno seguida de un cultivo limpio, que cuando la siembra se hizo directamente en el césped, y luego se prácticó un cultivo en franjas para evitar la erosión.

Se estudió qué efecto tuvo el número de plantas sembradas por cuerda y el abonamiento con el sistema de siembra directo en el césped y con cultivo en franjas.

Se produjeron 4 toneladas más de plátanos por cuerda sin que se les afectara su calidad, cuando se aumentó el número de plantas de 500, que es la práctica común, a 800 por cuerda. Cuando se aumentó el número de

plantas a 1,300 por cuerda no se notó aumento en la producción sobre la obtenida con 800 plantas.

Los plátanos respondieron marcadamente a las aplicaciones de 200 libras por cuerda de nitrógeno y de ácido fosfórico, pero no respondieron a las aplicaciones de cal, magnesio y potasio, debido a que el suelo contenía suficiente cantidad de estos nutrimentos en forma asimilable.

El contenido de nitrógeno, fósforo y potasio en la hoja aumentó con las aplicaciones de estos nutrimentos al suelo, pero las aplicaciones de magnesio y cal no afectaron el contenido de éstos en las hojas. Un contenido de menos de 2.8 por ciento de nitrógeno ó de 0.13 por ciento de fósforo en la hoja indica que hay deficiencia de estos elementos. De otro lado, un contenido de .60 por ciento de calcio, 0.24 por ciento de magnesio, ó 2.8 por ciento de potasa señala abundancia de estos elementos nutritivos.

Estos experimentos demuestran que en una cuerda pueden producirse 8 toneladas de plátanos con 5 toneladas de pulpa, cuyo valor nutritivo equivale al de la papa, en suelos inclinados de la región montañosa de Puerto Rico, lográndose a la vez una adecuada conservación del suelo.