Effect of Shade Trees on Yields of Five Crops in the Humid Mountain Region of Puerto Rico[1]

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INTRODUCTION

With the exception of coffee, cacao, and tea, there is little information available on the effect of shade trees on tropical crops. This information could be useful in many ways. Tropical forests thinned in preparation for planting shade-grown coffee, cacao, or tea, could be planted to shade-tolerant crops while the main crop comes into production. Even the classical "conuco" system of farming, in which a plot of land is cleared of trees, burned over, and cropped until soil fertility is depleted, could be improved through the use of shade-tolerant food crops. Instead of clearing the land completely, desirable trees could be left to reseed the area after the land is abandoned, thus improving the forests on a long-term basis while helping to feed the rapidly increasing tropical population. Information on shade tolerance is also important in developing economic systems of intercropping.

In Puerto Rico, thousands of acres of steep, shaded coffee plantings are being abandoned as production shifts to smaller, higher yielding, sun-grown plantings. If shade-tolerant crops could be grown under the existing shade trees, economic production could be combined with essential soil protection on these steep lands.

This paper presents the results of a study on the effects of shade trees on yields of tanniers, corn, plantains, tobacco, and bananas under typical conditions in the Humid Mountain Region of Puerto Rico.

MATERIALS AND METHODS

The experiment was conducted during 1963–64 near Jayuya, on a site 2,500 feet above sea level and exposed to the trade winds (NNE. exposure). Annual rainfall was about 73 inches, fairly well distributed throughout the year, except for a marked dry season from January through March. Mean annual temperature was about 72° F., with maximum variations

[1] This paper presents the results of an experiment carried out cooperatively by the Soil and Water Conservation Research Division, Agricultural Research Service, USDA, and the Agricultural Experiment Station of the University of Puerto Rico. Appreciation is expressed to Mr. Luis A. Becerra, on whose farm near Jayuya the field work was conducted.

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ranging from 55° to 83° F. A thick growth of trees and shrubs covered the land, formerly in shaded coffee but essentially abandoned during the last decade.

The soil is Los Guineos clay on a 40-percent slope with the following characteristics in the surface 6 inches:

pH		4.8
Organic matter	Percent	7.4
Nitrogen	Do	.3
Cation exchange capacity	Meq./100 gm.	24.5
Exchangeable calcium	Meq./100 gm	3.8
Exchangeable magnesium	Meq./100 gm	1.3
Exchangeable potassium	Meq./100 gm	.5
Exchangeable manganese	P.p.m.	46
Exchangeable aluminum	Do	121
Bulk density		1.1
Pores drained at ⅓ atm. of pressure	Percent	15.5

All vegetation was removed from the unshaded plots, but sufficient trees—mostly guavas (*Inga inga* (L.))—were left in the shaded plots to provide about 50-percent shade which was maintained by periodic pruning. Individual plots were 60 x 20 feet with 40-foot borders between plots. The treatments were replicated three times with each crop in a randomized block design.

All crops were planted in the undisturbed soil since Vicente-Chandler *et al.*[3] have shown that it is not necessary to till these soils. The crops were managed according to the best practices, and pests and diseases were controlled with the exception of the Sigatoka disease, a leaf spot caused by *Cercospora musae*, of bananas and plantains. This disease was not controlled, since spraying is not practiced at present in Puerto Rico because of the difficulty of carrying out this operation on the steep mountain lands at the required 10- to 15-day interval. Table 1 provides information on the crops tested.

Crop yields were determined for each plot. Average sunlight intensity in each plot was determined at noon on a clear day in July 1964, by making 10 measurements at random in each plot, using a Weston Model 603[4] sunlight meter.

[3] Vicente-Chandler, J., Caro-Costas, R., and Boneta, E.G., High Crop Yields Produced with or without Tillage on Three Typical soils of the Humid Mountain Region of Puerto Rico, *J. Agr. Univ. P.R.*, *50*(2): 146-50, 1966.

[4] Trade names and company names are included in this publication to provide information to the reader, and do not imply endorsement of the product listed by the U.S. Department of Agriculture or the Agricultural Experiment Station of the University of Puerto Rico, nor any claim for superiority over any other concerns or products.

RESULTS AND DISCUSSION

SUNLIGHT INTENSITIES

The following tabulation shows the foot-candles of light in the shaded plots: *i.e.*, Measurements were made immediately above the crop:

Replicate	*Average*	*Maximum variations within plots*
A	5,460	(2,400 - 10,400)
B	7,070	(2,400 - 11,400)
C	6,430	(2,100 - 10,800)
Average	6,320	

Sunlight intensity in the shaded plots was about half that in the unshaded plots (11,700 ft.-c.) and varied greatly from one location to another in the same plot.

TABLE 1. - *Information on crops tested in this investigation*

Crop	Variety	Plants per acre	Fertilization
		Number	*Lb./acre/crop*
Taniers	Morada	7,260 (3′ x 2′)	1 ton 10-6-20
Corn	Mayorbela	14,520 (3′ x 1′)	½ ton 14-4-10
Plantains	Maricongo	726 (6′ x 10′)	1 ton 10-6-20
Tobacco	Olor	9,680 (3′ x 1½′)	¾ ton 6-9-10
Bananas	Cavendish (Monte Cristo variety)	622 (7′ x 10′) and 871 (5′ x 10′)	1 ton 12-6-16

TOBACCO

The following tabulation shows the effect of shade trees on pounds of cured tobacco produced per acre:

Replicate	*Unshaded*	*Shaded*
A	1,771	1,614
B	2,119	1,656
C	1,195	1,310
Average	1,695	1,537

Similar high yields of cured tobacco were produced both in full sunlight and under shade trees. Shading did not affect appearance of the tobacco, which was all graded C1F or X1F, *i.e.*, of highest quality. This excellent crop of tobacco was grown during the off-season (March - July).

TANIERS

The following tabulation shows the effect of shade trees on pounds of taniers produced per acre:

Replicate	*Unshaded*	*Shaded*
A	13,100	2,100
B	12,500	3,000
C	7,800	3,500
Average	11,133	2,966

Shade trees reduced tanier yields to less than one-third of those produced in full sunlight.

CORN

The following tabulation shows the effect of shade trees on pounds of fresh corn on the cob produced per acre:

Replicate	*Unshaded*	*Shaded*
A	1,270	1,730
B	1,390	--
C	1,710	2,230
Average	4,470	1,980

Corn yields were severely decreased when grown under shade trees.

PLANTAINS

The following tabulation shows the effect of shade trees on pounds of plantains produced per acre:

Replicate	*Unshaded*	*Shaded*
A	16,520	14,350
B	16,870	15,540
C	15,190	11,900
Average	16,193	13,930
Fruits per acre	25,422	22,342
Fruits per bunch	36	32
Weight of fruit (pounds)	.64	.64

Shade trees slightly depressed plantain yields by decreasing the number of fruit per bunch. Fruit size was not affected by shading.

The following tabulation shows that shade trees almost prevented the development of leaf spot (Sigatoka) disease on 7-month-old plantains:

	Percentage of heavily infected leaves	
Replicate	*Unshaded*	*Shaded*
A	17.7	0
B	22.1	1.8
C	22.3	0
Average	20.7	0.06

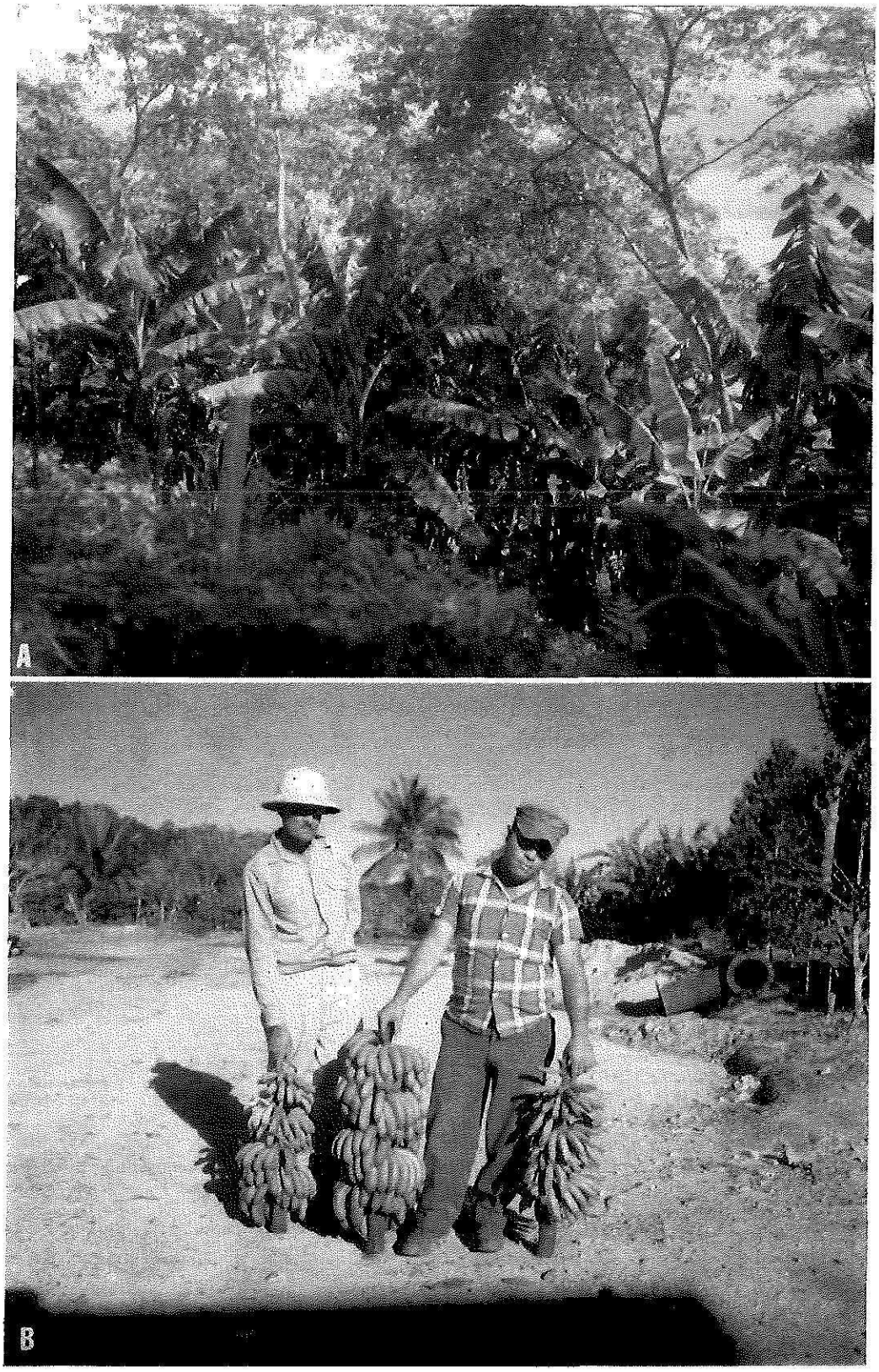

FIG. 1. A, Well-fertilized, healthy bananas growing in partial shade provided by "Guava" (*Inga inga* (*L.*)) trees. Note excellent protection afforded this steep soil by the shade and banana trees and by the close growing ground cover. B, Shaded bananas (center bunch) yielded 12 tons of marketable fruit per acre compared to only 6½ tons, produced in full sunlight where damage by leaf spot often prevented full development of the fruit (see left and right bunches).

BANANAS

Increasing population from 600 to 800 plants per acre increased yields of marketable bananas by about 5,000 pounds per acre, both in full sunlight and under shade trees (table 2). Bunch-size was not appreciably affected by population.

Twice as high yields of marketable bananas were produced under shade trees (fig. 1,A) than in full sunlight (table 1). Yields of over 12 tons of fruit produced with 800 plants per acre under shade trees are considered excellent.

The higher yields produced under shade resulted from the production of

TABLE 2.—*The effect of shade trees and plant population on pounds per acre of bananas produced at Jaguja*

Replicate	Unshaded		Shaded	
	600 plants per acre[1]	800 plants per acre[1]	600 plants per acre	800 plants per acre
A	9,360 (14,760)	12,480 (18,320)	21,060	23,200
B	7,440 (12,480)	12,160 (16,480)	16,800	21,160
C	8,880 (13,920)	14,400 (19,440)	20,520	27,360
Average	8,560 (13,720)	13,013 (18,080)	19,460	24,907
Average weight per bunch, pounds	14.3 (22.9)	16.3 (22.6)	32.4	31.1
Average hands per bunch, number	3.6 (6.3)	4.1 (6.3)	7.1	7.1

[1] Figures in parentheses are for total yields. All bananas produced under shade were marketable.

heavier bunches due to better development of the fruit (fig. 1,B). This, in turn, is explained by the lower incidence of leaf spot as shown in the following tabulation giving the percentage of banana leaves severely damaged by leaf spot when the planting was 7 months old:

Replicate	*Unshaded*	*Shaded*
A	51.0	16.1
B	50.0	26.2
C	47.7	32.7
Average	49.4	25.0

Leaf spot damage increased so rapidly as the plants matured, that many of the sun-grown plants had no healthy leaves at all and were incapable

of developing the lower hands (fig. 1,B). The attenuating effect of the shade trees on leaf spot is apparently related to reduced dew formation on the shaded banana leaves.

The shaded bananas matured somewhat later and at a more uniform rate than those growing in full sunlight. Only 38 percent of the shaded bananas were harvested during the sixteenth and seventeenth months after planting, compared to 65 percent of those grown in full sunlight. The high elevation accounts for the rather late maturity in both cases.

The production of high yields of bananas under shade trees, in locations where spraying for control of leaf spot is impractical because of steepness of the land, small size of holdings, lack of trained personnel, etc., has important implications. Under such conditions, the production of bananas under shade trees could be a practical and profitable enterprise. In some cases it might be possible to improve tropical forests by thinning to leave only desirable trees to reseed the area, and planting bananas as a temporary cash or food crop. In Puerto Rico's Mountain Region, thousands of acres of shaded coffee plantations are being abandoned as production shifts to smaller, higher yielding, intensively managed, sun-grown plantings. There are few alternative uses for this land, much of which, with shade trees extant, could be put into profitable, stable production by planting to bananas. Cost of bringing an intensively managed, lightly shaded banana plantation into production over a 1-year period is estimated at $200 per acre, with a net profit of $100 to $200 per acre yearly thereafter.

This system of producing bananas allows for excellent erosion control in the steep mountains which are the main source of the Island's limited water supply. Part of the tree cover is retained, the bananas are planted directly in the undisturbed soil and the natural ground cover is maintained. Since bananas bear for many years the soil is protected continuously by the combination of ground cover, banana and shade trees (fig. 1,A).

SUMMARY

The effects of trees, providing about 50 percent of shade, on yields of tobacco, corn, taniers, plantains, and bananas were determined in the Mountain Region of Puerto Rico, with annual rainfall of about 73 inches and a mean annual temperature of 72° F.

Shade trees severely reduced yields of taniers and corn, reduced those of plantains only slightly, and did not affect yields of tobacco.

Bananas produced twice as high yields of marketable fruit under shade than in full sunlight because of reduced damage by leaf spot (Sigatoka) disease. The possibility of converting abandoned, shaded coffee plantations to high productivity, together with conservation, by growing bananas

in undisturbed soil with natural ground cover under shade trees is promising.

RESUMEN

Se determinó el efecto de una sombra de aproximadamente 50 por ciento producida por árboles, sobre los rendimientos de tabaco, maíz, yautía, plátanos y guineos en la Región Montañosa de Puerto Rico, con lluvia de 73 pulgadas anuales y una temperature media de 72° F.

La producción de maíz y yautías se redujo marcadamente a la sombra y la de plátanos muy levemente. Sin embargo, la sombra no tuvo efecto sobre la producción de tabaco.

La producción de guineos para el mercado fué dos veces mayor a la sombra que a pleno sol, debido a una menor incidencia de la mancha de las hojas (Sigatoka) cuando se sembraron a la sombra. Se discute la posibilidad de producir guineos lucrativamente en plantaciones de café abandonadas, dejando poca sombra y la vegetación cobertora natural, para proteger el suelo contra la erosión.

ERRATA

The four illustrations which appear as figure 6, Journal of Agriculture of the University of Puerto Rico, Vol. L, No. 4, October 1966, should be identified as follows: upper on page 328 as Taiwanica, lower on page 328 as Mexican; upper on page 329 as Parson Brown, and lower on page 329 as Changsha.