Differential Response of Some Tropical Soils to Additions of Organic Matter

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INTRODUCTION

The question of soil organic-matter depletion in tropical areas is frequently brought up in exaggerated terms. This has been because of the prevailing ideas that organic-matter levels are low in all tropical soils as compared to soils of the Temperate Zone. Smith, *et al.* (9)[2] have shown that the organic-matter contents of tropical soils of Puerto Rico are at least as high as those of many of the best soils of the Temperate Zone.

This paper reports attempts to show the differential response of certain tropical soils of Puerto Rico to organic-matter additions. For these purposes data have been gathered from six field experiments in the humid region of Puerto Rico in areas of latosolic and nonlatosolic soils. Data will be presented in support of the hypothesis that additions of organic-matter sources to normal, moderately fertile latosols with an open, porous structure are of rather doubtful value, while such additions may increase the organic-matter levels of heavy-textured nonlatosolic soils of moderate fertility which are in an unfavorable physical condition.

EXPERIMENTAL PROCEDURES

FIELDWORK

Six field experiments from which the data herein presented were obtained, will be discussed briefly. Complete details about each one have been presented elsewhere (2, 3, 4, 5, 6, 7, 8). Data from each are brought together and analyzed here with the main objective of detecting the influence that organic-matter additions may exert on soils of different nature. Table 1 gives information regarding the location, soil type and group, type of experiment, duration, and indicator crop used.

Experiment 1 was conducted from March 1944 to March 1948, with the primary purpose of evaluating the practice of mulching with sugarcane trash as compared to burning it, from the soil conservation standpoint. The soil was a Catalina clay, a very deep reddish-brown latosol, with a 45- to 50-percent slope. Four crops of sugarcane were harvested. Each of the

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[2] Numbers in parentheses refer to Literature Cited, pp. 76–7.

TABLE 1.—*General information concerning the 6 field experiments from which data on soil organic matter and nitrogen levels are reported*

Experiment identification No.	Location	Soil type and group	Type of experiment	Indicator crop
1	Mayagüez	Catalina clay—latosol	Trash handling	Sugarcane
2	Isabela	Coto clay—latosol	do.	Do.
3	Río Piedras	Vega Alta silty clay—nonlatosol	do.	Do.
4	Arecibo	Bayamón silty clay—latosol	Filter press-cake evaluation	Pineapple
5	Corozal	Lares clay—nonlatosol	do.	Do.
6	Mayagüez	Catalina clay—latosol	Green-manure	Sweetpotatoes, corn

first three crops received a 14–6–8 fertilizer at a rate of 1,200 pounds to the acre, but the fourth crop received only 600 pounds of the same fertilizer. Run-off plots with catchment tanks facilitated the measurement of soil and water losses. Bulk samples from the upper 6 inches of soil were taken following the last harvest.

Experiment 2 has been under way for the past 7 years on a Coto clay, a yellowish-brown latosol in very good physical condition, highly porous, but of moderately low fertility. The procedures for handling the sugarcane trash were as follows: Trash aligned, trash aligned and clean banks furrowed, trash left undisturbed over the surface, and trash burned. The field as a whole receives each year an application of 1,200 pounds to the acre of a 15–3–10 fertilizer. Bulk samples from the upper 6 or 8 inches of the soil, and soil cores at 0 to 3 and 4 to 7 inches, were taken after harvesting the sixth crop.

Experiment 3 has been going on for the past 10 years on a nearly level Vega Alta silty clay, a nonlatosol of moderate fertility, rather heavy, and imperfectly drained. The sugarcane trash is handled yearly after harvest in each of three ways, namely, aligned in alternate banks, buried, or burned. Each crop was fertilized in the same way as the Isabela experiment previously described. Following the sixth ratoon-crop (seventh in the crop cycle) harvest, soil samples were taken for laboratory analyses.

Experiments 4 and 5 were designed to test the influence of filter-press cake on pineapple yields and soil properties. The experiments were rather complex, involving four levels of filter-press cake, and five of fertilizer, liming, and iron sprays. In this paper only two levels of filter-press cake,

where all other variables were kept constant, will be considered. In one treatment, filter-press cake was worked into the surface 6 inches of soil at a rate of 32 tons to the acre, and a 12–6–10 fertilizer was applied after planting at a rate of 3,000 pounds to the acre. No filter-press cake was used in the other treatment, but the same quantity of fertilizer was applied. Bulk samples were taken at both experimental fields following harvest, some 20 months after treatment, and to a depth of 6 inches. In addition, 1- to 4-inch-deep soil cores were taken in experiment 5. Experiment 4 was located on a Bayamón silty clay, an acid, deep latosol of the coastal plains, in very good physical condition, but of rather low fertility. Experiment 5 was located on a Lares clay, a medium-friable nonlatosol occurring in terrace formations.

Experiment 6 was conducted on a Catalina clay, a latosol, in the same general area where experiment 1 was laid out. The following crop rotation was used: Two legume crops, one sweetpotato crop, two legume crops, and two corn crops. The legume crops were fertilized with lime at a rate of 4 tons and phosphorus at a rate of 100 pounds of P_2O_5 to the acre. The second corn crop was fertilized with muriate of potash at a rate of 250 pounds of K_2O and superphosphate at a rate of 100 pounds of P_2O_5 to the acre. The equivalent of 4.5 to 6 tons of green manure was incorporated into the soil per crop of velvet beans, or a total of 9 to 12 tons from the two crops of velvet beans, before planting sweetpotatoes and corn, respectively. Soil samples were taken after the first corn crop (sixth on the rotation) was harvested.

LABORATORY WORK

Organic-matter determinations were made on all soil samples by the chromic acid titration method, as modified by Walkley and Black (11). Total nitrogen was determined by the standard Kjeldahl method. In experiments 2, 3, and 5, measurements were made of water retention at pF 1.78 by using tension tables. Other chemical and physical data were obtained from bulk and core soil samples, but they have been presented elsewhere previously (6, 7, 8).

RESULTS

A summary of the data pertaining to soil organic-matter and nitrogen levels in soils of different nature following differential organic-matter-management practices is given in table 2. The data from experiment 1 indicate that mulching with sugarcane trash did not affect the organic-matter level of this latosol. The following tabulation, adapted from data of Bonnet, *et al.* (2), gives the weighted mean yields and soil losses for the duration

TABLE 2.—*Organic-matter and nitrogen levels of humid-region tropical soils of different nature following differential organic-matter management*

Experiment identification No.	Soil group	Soil treatment	Soil organic-matter level	Soil nitrogen
			Percent	*Percent*
1	Latosol	Sugarcane trash used as mulch	3.73	0.20
		Sugarcane trash burned	3.75	.23
2	do.	Sugarcane trash aligned	2.71	.19
		Sugarcane trash aligned and clean banks furrowed	2.51	.18
		Sugarcane trash left undisturbed	2.54	.18
		Sugarcane trash burned	2.66	.18
3	Nonlatosol	Sugarcane trash aligned	1.70	.14
		Sugarcane trash buried	1.82	.15
		Sugarcane trash burned	1.42[1]	.14
4	Latosol	32 tons per acre of filter-press cake	2.42	.15
		No filter-press cake	2.34	.14
5	Nonlatosol	32 tons per acre of filter-press cake	2.81[2]	.17
		No filter-press cake	2.26	.15
6	Latosol	18 to 24 tons per acre velvetbean leaves and vines	1.90	.17
		No green manure	1.80	.17

[1] Highly significant levels in trash aligned and buried as compared to trash burned.
[2] Significant difference between treatments.

of the experiment:

	Mulched	*Unmulched*
Sugar yields (tons per acre)	3.3	3.5
Soil losses (tons per acre)	.7	7.2

Where the cane trash was returned to the soil as a mulch, erosion losses were only one-tenth as compared with those when it was destroyed. However, even the continuous burning of the trash caused no measurable decline in sugar yields or in soil organic-matter or nitrogen levels during the 4-year period of the test, but mulching was an effective soil conservation practice in this latosol with a 45- to 50-percent slope.

Data from experiment 2 further show that no significant difference in the organic-matter content of latosols could be measured after 5 years of either burning or returning the sugarcane trash to the soil. Yields were not affected either (6). However, from a practical standpoint it might prove economically advantageous to leave the trash undisturbed over the surface of the soil in many areas. Weeds will be smothered to a large extent thus

decreasing cultivation costs. In addition, direct moisture-vaporization losses from the soil could be reduced.

The results of the analytical work with the samples of nonlatosolic soil taken from the plots of experiment 3 disclosed significantly lower organic-matter levels where the trash was burned than where it was either buried or aligned. In a previous publication (5) it was shown that the effect of these treatments after 6 years of continuous cane growing was reflected in significant yield differences favoring trash conservation as compared to trash burning.

As is shown in table 2 the organic-matter content of Bayamón silty clay, a latosol, was not affected by the addition of 32 tons of filter-press cake to the acre. However, when the same treatment was given to the nonlatosolic Lares clay it resulted in significantly increasing the organic-matter content of the soil from 2.26 to 2.81 percent. The following tabulation summarizes the yield response, in tons per acre of pineapples, attributable to treatment in these two experiments:

Filter-press-cake application	*Yield on latosol*	*Yield on nonlatosol*
0	20.32	14.42
32 tons per acre	21.48	19.76

Yield increases of over 5 tons of fruit could be attributed to some extent to improving the organic-matter level of the nonlatosolic soil.

Table 2 further shows that no increases in the soil reserves of organic matter and nitrogen of the latosol Catalina clay could be measured after incorporating velvet bean green manure. However, significant yield increases of sweetpotatoes and corn were obtained (3). Perhaps, the increased yields were attributable to an increased nitrogen supply through the activity of the legume. This nitrogen was used quickly by the growing crops. The rapid release of nitrogen under tropical conditions has been emphasized lately (10). A legume mulch can provide an economical and continuous supply of nitrogen for plant growth.

Soil-moisture retention at tensions in the vicinity of pF 1.78 increased in response to soil organic-matter increases in nonlatosols as follows: From 45 to 60 percent when sugarcane trash was conserved rather than destroyed through burning (experiment 3) and from 36 to 40 when filter-press cake was added at the rate of 32 tons to the acre (experiment 4). No increases in moisture retention at pF 1.78 were measured in a latosol where soil organic-matter levels remained unaffected by treatment.

DISCUSSION

The tropical soils of Puerto Rico vary widely in their nature, mainly in response to variations in climatic factors. Those of the humid regions can be roughly grouped into two broad divisions, lateritic soils or latosols and

nonlatosols or nonlateritic soils. The latosols are products of the humid tropical weathering of rocks which are usually basic in reaction, resulting in acidic material high in free sesquioxides, low in free silica, of moderate exchange capacity, very permeable to air and water, and in many instances, of great depth, but exhibiting rather little differentiation into soil horizons. They have a high clay content with predominance of kaolinite and iron oxides in the clay fractions. They are generally found in regions with mean annual temperatures above 70°F., and annual rainfall above 60 inches. They can be easily worked even after a rain, and are rather resistant to erosion as compared with other soils of similar climatic and relief conditions and under identical systems of management.

Nonlatosols of the humid tropical areas are generally heavier than their latosolic textural equivalents, even when they contain the same clay on a percentage basis. Generally, in addition to kaolinite, there are other clay minerals of the 2:1 lattice type in their clay fraction. They are not as permeable to air and water, often present practical drainage problems, and are rather difficult to work and manage during the rainy season.

In general terms, it has been shown (9) that there are rather high reserves of organic matter and nitrogen in the soils of Puerto Rico. Their full utilization and conservation appears to be a worthy goal for crop production and fertility maintenance in the Island. The predominant factors in the organic-matter balance are mostly climatic or perhaps climatic and biotic. Thus, latosols which are rather old soils, have probably reached a level of equilibrium with the surrounding ecological forces, and under natural conditions, or under proper conservation farming, approach their maximum retention of organic matter. Aeration and leaching, which are favored by the physical condition of latosols, are in good measure the controlling factors.

The evidence presented in this paper tends to show that the addition of low-nitrogen organic-matter sources, such as sugarcane trash and filter-press cake, to latosols for the purpose of raising their organic-matter contents, is of rather doubtful value, since organic-matter levels remain unaffected and crop yields are not improved. Data[3] obtained from a field of Coto clay (a yellowish-brown latosol) that has been for over 20 years in cane show an organic-matter level of approximately 3 percent. Subsequently, a section of that field was used to grow clean-cultivated crops for 4 years, while the rest was planted to cane continuously. The levels of organic matter remained unaffected. The response in food-crop yields reported from legume green-manure additions to a latosol may well be explained on the basis of the increased and continuous nitrogen supply available to the food-crop plants following the legume crops.

[3] Vicente-Chandler, J., Unpublished data from Agricultural Research Service Cooperative Project, 1953.

There was a marked response to low-nitrogen organic-matter sources in the humid-region nonlatosolic soils which resulted in significant increases in the soil organic-matter level. It must be kept in mind that these soils were reasonably well fertilized both for the sugarcane and pineapple crops. Significant yield increases of both crops were obtained which may be attributed to the favorable effects of increased organic-matter levels on the physical condition of the soils.

Most studies along this line have shown that measurable changes in the organic-matter level of soils cannot be determined with precision over a short period of years. However, the data presented in this paper provide important reference points of what to expect from organic-matter additions to soils of different nature.

SUMMARY

Data are presented in support of the hypothesis that additions of organic-matter sources to normal latosols with an open, porous structure are of rather doubtful value, while in heavy-textured nonlatosols of moderate fertility, but unfavorable physical condition, such additions may result in increased organic-matter levels. No increases were measured when latosols were treated with different quantities of sugarcane trash, filter-press cake, and velvet bean green manure. Definite increases were obtained from the same treatments in nonlatosols.

RESUMEN

Se presentan aquí datos para verificar la hipótesis de que las adiciones de materia orgánica a suelos lateríticos, de condición física favorable, son de valor dudoso; mientras que en el caso de suelos no lateríticos, con condiciones físicas desfavorables, estas aplicaciones pueden aumentar efectivamente los niveles de materia orgánica.

No su pudieron medir aumentos en el contenido de materia orgánica de suelos lateríticos cuando se trataron con diferentes cantidades de paja de caña, cachaza y abonos verdes de habichuelas terciopelo. En suelos no lateríticos se midieron aumentos positivos cuando se trataron en la forma descrita anteriormente.

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