THE HANDLING OF SUGARCANE TRASH

II. EFFECTS OF VARIOUS PRACTICES ON SOIL PROPERTIES

M. A. Lugo-López, P. Landrau Jr., and G. Samuels[1]

Introduction

The sugarcane crop leaves a large residue of plant material after harvesting which consists mostly of green tops, roots, and dry trash. The green tops, as a rule, are used as fodder for farm livestock. The roots remain in the soil and contribute to the maintenance of the organic-matter level. The dry trash, consisting of all the leaf blades and sheaths, is left on the field where it is either burned, buried, aligned in alternate banks, or left undisturbed as a mulch over the surface of the soil.

Hardy and Evans (4)[2] estimated that for every 4 tons of green millable cane a ton of trash was produced. Bonnet, et al (2) report a mean cane-trash ratio of 5:1 from a plant crop and three ratoons of POJ 2878 raised at Mayaguez from 1945 to 1948. For the Puerto Rican 1949 crop where nearly 11 million tons of cane were harvested from 359,743 acres, this amounts to returning almost 8 tons of dry trash to the acre, taking Hardy's ratio (9, 11) as a basis.

Bonnet, et al compared the effect of leaving the trash as mulch or burning it, for four crops of sugarcane (1944–1948) grown in a lateritic soil with a 40-percent slope. No significant differences in yields were found between treatments. However, highly significant differences were found between soil losses, the unmulched plots loosing about 11 times as much soil as the mulched ones (2). Landrau and Samuels (6) have reported previously on yields and economic considerations as affected by different methods of handling trash in experimental fields at Isabela and Río Piedras.

At Isabela no differences in yields were observed for four crops of cane (1946–1950) whether the trash was aligned, burned, buried, or left as a mulch over the surface. At Río Piedras the effects of burning, burying, or aligning the trash in alternate rows were compared and there were no significant differences in the yields per acre of available 96° sugar for the first four ratoon crops. However, the plots where the trash had been aligned gave significantly higher yields of sugar in the fifth and sixth ratoons than those where it was either burned or buried. The plots where the trash was burned

[1] Associate Soil Scientist, Assistant Agronomist, and Plant Physiologist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited, p. 254.

tended to produce yields lower than those where it was buried, but the differences were not significant.

This paper reports on soil conditions at the experimental field at Río Piedras where treatment differentials have been established for the last 6 years, 1945–1951 (6).

Materials and Methods

The trash-handling experimental field at Río Piedras was established in 1945 at the Solís farm in an area previously mapped as Vega Alta silty clay, a rather extensive sugarcane soil of the humid area (10). A soil profile to a depth of 72 inches obtained at the middle of the experimental field on April 2, 1951, by using a Kelley soil-sampling machine (5), revealed a very dark grayish-brown (10 YR 4/2) surface of about 11 inches in depth with a moderately developed angular structure. The 12–29-inch layer was yellowish red (5 YR 5/8) with considerable red mottling and a moderately developed subangular structure. The 30–72-inch layer was a yellowish brown (10 YR 5/8) silty clay loam, with red and gray mottling.

The procedures for the handling of the trash in each treatment were as follows:

Trash burned: The trash was spread evenly over the plot and burned.

Trash aligned: The trash was aligned in alternate banks.

Trash buried: A furrow was made about 1 foot deep between rows; the trash was placed in the furrow and covered with soil.

The treatments were repeated every year after harvest. Each treatment was replicated 20 times. The plots were 150 feet long by 20 feet wide and the cane rows were 4 feet apart. The plots were arranged following a randomized block lay-out. The variety of cane used was POJ 2878. The field as a whole received an application of 1,200 pounds of a 15–3–10 fertilizer every year. After the sixth ratoon was harvested, infiltration tests were run in the field and samples taken from each plot for laboratory analysis.

Bulk composite samples were taken from the topmost 6 or 8 inches of soil. Each composite consisted of 10 samples. Undisturbed cores, 3 inches in diameter and 3 inches in length, were also taken at two depths, 0–3 inches and 4–7 inches, by making use of a Bradfield soil sampler. The buffer-compartment method outlined by Nelson and Muckenhirn was used (7) to determine the infiltration rate. Iron rings 9, 18, and 27 inches in diameter were jacked into the soil. A $\frac{1}{4}$-inch head of water was maintained in the center ring by means of a self-dispensing calibrated 2,000 c.c. burette. The same hydraulic head was maintained in the outer compartments to minimize lateral movement of water from the inner ring where measurements were taken by the hour. The tests were run for 8 consecutive hours.

Permeability measurements were made in undisturbed soil cores by recording the rate at which water moved through a column of saturated soil at a known head. Special equipment described by Smith, Furhiman, and Silva (12) was used in making these measurements. Quick drainage was determined by putting the saturated core in a Büchner funnel, setting a 60 cm. tension, and measuring the water drained out at the end of 15 minutes. The water removed and retained at pF 1.78 was measured by bringing the soil core to equilibrium with a 60-cm. tension and determining the variation in weight of the core. The maximum saturation was calculated from the above data.

The soil core was finally dried in the oven at 110°C. As the samples used had a definite known volume, the bulk density of the soil was calculated by dividing the net dry weight of soil by its volume. The pore space was then calculated by assuming a specific gravity of 2.65. The air porosity, as used in this paper, is the difference between the theoretical pore space and the volume of water retained at pF 1.78.

TABLE 1.—*Mean pH, nitrogen, organic matter, and C/N ratio of soils from the trash-handling experimental field at Río Piedras*

Treatment	Treatment	pH	Nitrogen	Organic matter	C/N ratio
			Percent	*Percent*	
A	Trash burned	5.08	0.145	1.425	5.7
B	Trash buried	4.92	.149	1.825[2]	7.8[1]
C	Trash aligned	5.03	.144	1.700[2]	7.0
L.S.D. at the 5-percent level		.179	.018	.223	1.70
L.S.D. at the 1-percent level		.239	.024	.298	2.27

[1] Significant at the 5-percent level.
[2] Significant at the 1-percent level.

The pH was determined electrometrically by means of a Macbeth pH meter. Total nitrogen was determined by using the standard Kjaldahl method and the organic matter by the simple colorimetric Schollenberger technique. The carbon-nitrogen ratio was subsequently calculated from the above data.

RESULTS AND DISCUSSION

The results of the chemical analysis of the soils taken from the Río Piedras trash handling experimental field are shown in table 1. The general pH values ranged between 4.5 and 6.2 with a mean value of pH 5.0 for soils under all treatments combined. There were no significant differences between the means of the treatments. The mean nitrogen content of soils under all combined treatments was 0.146 percent. There were no significant differences between the mean nitrogen content of soils from the plots, whether the trash was burned, buried, or aligned. However, soil from the plots where the trash was either buried or aligned had a much higher organic-matter content than that from those where it was burned. After 6 years of establishing the treatment differentials, the accumulated differences were clearly marked. The results were highly significant.

The plots where the trash was aligned or buried had been receiving not less than 8 tons of trash to the acre after each harvest, which amounts to 48 tons during the cycle of one plant crop and five ratoons. The accumulation of organic matter in the soil is a rather slow process. Regarding the weight of the acre-furrow-slice as 2 million pounds, the organic residues added during the crop cycle should amount to 4.8 percent. However, it must be considered that a large proportion of the organic matter added is decomposed by the micro-organisms of the soil, releasing essential nutrients for plant growth.

Furthermore, the sugarcane trash has a wide C/N ratio of about 40:1 (1, 8). By the time the residues become an integral part of the soil, this ratio is usually narrowed to 10:1. Thus the 48 tons of organic material become 12 tons of organic matter with a C/N ratio of 10:1, which is equivalent to 1.2 percent of organic matter in the plow layer. This decomposition of the trash is rather rapid under the climatic conditions of the Tropics which greatly hasten such processes. Therefore, in spite of the seemingly large additions of plant residues to the plots where the trash was buried and aligned, as compared with those where it was burned, the increases in organic-matter content in soils from the first two as compared with the last were only 0.4 percent for burying and 0.3 percent for aligning. There were no significant differences between the effects of burying and aligning the trash.

The mean soil C/N ratios were 5.7, 7.8, and 7.0 for the burned-, buried-, and aligned-trash treatments respectively. The difference between burying and the burning is significant. In general, the ratio was narrower in the plots where the trash was burned. In the other plots which received large quantities of carbonaceous plant material for 6 consecutive years, the ratio was a little wider. However, all these ratios considered together were less than 10:1, which indicates that the trash decomposed quickly. No wide C/N ratios indicative of slow decomposition were observed. The field as a whole received a yearly application of 1,200 pounds of 15–3–10 fertilizer to the acre, which insured an adequate supply of nitrogen for both micro-organisms and plants during the early critical stages of crop growth.

Table 2 gives the mean infiltration rate of the soil determined for each of 8 hours on plots where the sugarcane trash was differently handled for the past 6 years.

In general, the soil infiltration rate was slower in the plots where the trash was burned than in those where it was either buried or aligned. Burying the trash disturbed these plots mechanically every year in the making of a furrow between cane rows which promoted a higher rate of infiltration. This high rate of infiltration is especially beneficial in Puerto Rico where heavy rainfalls of short duration are not uncommon. Soils with a lower infiltration rate cannot absorb as much water and most of the rain is lost as runoff. Whether significant differences in infiltration rates will be obtained with larger accumulations of organic matter in the soil remains to be seen.

In addition to the infiltration rates determined under field conditions, a number of undisturbed soil cores was taken for soil-moisture studies

TABLE 2.—*Rate of infiltration of soils where sugarcane trash was burned, buried, or aligned for 6 consecutive years*

Treatment	Treatment	Infiltration rate in inches of water per hour at hour indicated							
		1	2	3	4	5	6	7	8
A	Trash burned	7.54	2.76	2.00	1.76	1.98	1.55	1.35	1.40
B	Trash buried	14.77	7.06	4.04	3.56	3.17	2.50	2.96	2.38
C	Trash aligned	9.93	4.36	3.10	3.05	2.78	2.47	2.34	2.00
Minimum required for significance at the eighth hour									3.11

under laboratory conditions. The results of the permeability tests and other soil-moisture measurements performed are reported in table 3.

In general, there were no outstanding or significant differences in the moisture characteristics of the soils undergoing the various trash-handling treatments. Some trends, however, should be pointed out. Perhaps they will become significant when the anticipated larger differences in organic-matter levels occur in later years as a result of some methods of handling the trash. The movement of water as indicated by permeability measurements appeared to be slower in the soil of plots where the trash was burned than in the others. Soil from plots where the trash was aligned in alternate rows seemed to have a higher moisture content at maximum saturation than that from plots which underwent either one of the other treatments. More water was removed from soil cores that reached equilibrium with a 60-cm. tension when they came from the plots where the trash was burned than when they came from plots where it was either buried or aligned. The last column of table 3 indicates that the upper layer of soil from the plots where the trash was aligned retained more water at low tensions than that from plots where the trash was buried or burned. Soil from the plots where the trash was burned retained the least volume of water at pF 1.78. In all probability this water was readily available, the plants being able to remove it quickly until tensions in the vicinity of the permanent wilting percentage (pF 4.2) were reached.

Although the recorded differences were not significant, it does appear that, when carried out over a period of years, trash burning is not a beneficial practice, at least insofar as total water retention is concerned; perhaps the total available water is also reduced. This may have a bearing upon cane and sugar yields. Aligning the trash has been previously reported to produce significantly higher sugar yields than either of the other two

TABLE 3.—*Permeability and other soil-moisture data gathered from soil cores collected from the trash-handling experimental field at Río Piedras*

Treatment	Treatment	Sampling depth	Permeability	Water drained at 60 cms in 15 minutes	Maximum saturation	Water removed at pF 1.78	Water retained at pF 1.78
		Inches	*In./hour*	*Inches*	*Percent*	*Percent*	*Percent*
A	Trash burned	0–3	0.51	2.65	50.92	5.42	44.97
		4–7	1.60	.77	51.80	2.30	49.40
B	Trash buried	0–3	.44	1.38	49.90	3.58	46.15
		4–7	4.00	1.15	50.47	2.65	47.80
C	Trash aligned	0–3	.80	2.25	54.70	4.70	50.00
		4–7	6.67	.98	52.42	2.68	49.70
Minimum required for significance		0–3	.53	1.51	3.42	2.01	4.39
		4–7	9.39	.48	1.72	1.12	1.67

treatments at the fifth and sixth ratoon crops. No significant differences were observed in the earlier four crops in the cycle (6). The accumulation of organic matter in the soil with the consequent, although slow, change in its physical nature, may serve to explain yield differences.

Table 4 presents data on bulk density, total porosity, and air porosity of soils taken from the variously treated plots. The bulk-density values range from mean values of 1.26 gm./c.c. for soil from the plots where the trash was burned or buried to 1.19 gm./c.c. for the soil under the aligned-trash treatment. The mean porosity value for soil from all plots was 52.54 percent by volume, with deviations of only 2.54 percent above or below. The air porosity was highest for soil from plots where the trash was burned, next highest from those where it was buried, and lowest from those where it was aligned. The air porosity was in inverse relationship to the water porosity (water retained at pF 1.78) the total pore space being more or less constant.

The incorporation of large amounts of organic residues in a continuous, steady way for a number of years probably produces a better state of aggregation and consequently the formation of a larger proportion of microaggregates capable of holding considerable quantities of water at relatively low tensions. This fact has been substantiated by Browning and Milan (3) and others who found significant increases in aggregation with each unit increase in organic matter. The larger the air porosity, the larger the proportion of coarse pores, and therefore relatively less water is available for crop growth.

TABLE 4.—*Bulk density, pore space, and air capacity of soils from the sugarcane trash-handling experimental field at Río Piedras*

Treatment	Treatment	Sampling depth	Bulk density	Pore space	Air porosity (pore space-water retained at pF 1.78)
		Inches	*Gm./c.c.*	*Percent*	*Percent*
A	Trash burned	0–3	1.26	52.45	7.48
		4–7	1.28	51.47	2.07
B	Trash buried	0–3	1.26	52.25	6.10
		4–7	1.28	51.68	3.88
C	Trash aligned	0–3	1.19	55.12	5.12
		4–7	1.26	52.63	2.93
Minimum required for significance		0–3	.097	3.98	—
		4–7	.048	2.10	—

SUMMARY

Data are presented here for various soil characteristics on plots where the sugarcane trash had been either burned, buried, or aligned in alternate rows for 6 consecutive years in a plant and 6-ratoon crop cycle. The experiment was established in a Vega Alta silty clay, a rather extensive sugarcane soil of the humid area. After the sixth ratoon crop was harvested, infiltration tests were run in the field and bulk and core samples taken for laboratory analysis. No significant differences were observed between the mean pH and total nitrogen values of soil under the various treatments. The mean organic-matter content of soil from plots where the trash was burned was significantly lower, at the 1-percent level, than that of soil from plots where it was buried or aligned. The C/N ratio was narrow in all cases, but lower under the burned-trash treatment.

The mean infiltration rates at the eighth-hour run were 1.40, 2.00, and 2.38 inches per hour for soils that underwent the burned-, aligned-, and buried-trash treatments, respectively, but the differences were not significant. No significant differences were observed between the means of the various physical measurements performed, namely, permeability, quick drainage, maximum saturation, water removed and retained at pF 1.78, bulk density, total porosity, and air porosity. Some trends observed may become significant with continuous accumulation of organic matter in soils undergoing the buried- and aligned-trash treatments. For instance, the permeability of soils from plots where the trash was burned tended to be lowest, and the upper layer of soil from plots where the trash was aligned seemed to retain more water at low tensions than the upper layer of soil from plots treated otherwise.

Resumen

En este estudio se presentan datos sobre varias propiedades del suelo en aquellas parcelas donde la paja de la caña de azúcar se quemó, se enterró, o se alineó en hileras alternadas, por seis años consecutivos. El campo donde se estableció el experimento está formado por una arcilla limosa de la serie Vega Alta. Este suelo, propio para la caña, se encuentra bastante extendido por toda la zona húmeda de Puerto Rico.

Después de la cosecha del sexto retoño, se hicieron pruebas de infiltración en el campo y se tomaron muestras, incluyendo columnas de suelo en su estado natural, para analizarlas en el laboratorio. No se observaron diferencias significativas entre los valores pH y el contenido de nitrógeno total promedio de cada tratamiento. El contenido promedio de la materia orgánica de las parcelas, donde se quemó la paja de caña, resultó ser significativamente más bajo (al 1 porciento) que el de aquellas parcelas donde se enterró y se alineó la paja en hileras alternadas. La razón C/N fué baja en todos los tratamientos, y menor en las parcelas donde se quemó la paja. Las pruebas de infiltración en el perfil, dieron, como promedio, 1.40, 2.00, y 2.38 pulgadas por hora a la octava hora, en las parcelas donde la paja se quemó, se alineó y se enterró, respectivamente. Sin embargo, las diferencias no fueron estadísticamente significativas.

No se observaron diferencias significativas entre los promedios de las varias propiedades físicas medidas, a saber: permeabilidad, agua removida en 15 minutos a una tensión de 60 centímetros, saturación máxima, agua removida y retenida a pF 1.78, peso por volumen, porosidad total y proporción de poros gruesos. No obstante, se observaron algunas tendencias que podrían resultar significativas si se continuara la acumulación de la materia orgánica, tal y como occurre en las parcelas donde la paja de caña se entierra y se alínea. Por ejemplo, se observó que la permeabilidad aparentemente fué más lenta en las parcelas donde se quemó la paja. El suelo

de las parcelas, donde se alineó la paja pareció capaz de retener más humedad en su capa superior a tensiones bajas, que el de las parcelas que recibieron otros tratamientos.

Literature Cited

1. Bonnet, J. A., Nitrogen transformations in the decomposition of sugarcane trash, with special bearing upon Puerto Rico soil problems, *Jour. Dept. Agr. P. R.* **15**(2) 113–146, 1931.
2. Bonnet, J. A., Abruña, F., and Lugo López, M. A., Trash disposal and its relation to cane yield, soil and water losses, *Jour. Agric. Univ. P. R.* **34**(3) 286–293, 1950.
3. Browning, G. M. and Milán, F. M., Rate of application of organic matter in relation to soil aggregation, *Soil Sc. Soc. Amer. Proc.*, **6** 96–97, 1941.
4. Hardy, F. and Evans, L. J. C., Yields of sugarcane trash, *Trop. Agr.* **23** 224–225, 1946.
5. Kelley, O. J., Hardman, J. A., and Jennings, D. J., A soil sampling machine for obtaining two, three and four inch diameter cores of undisturbed soil to a depth of six feet, *Soil Sc. Amer. Proc. of 1947*, **12** 85–87, 1948.
6. Landrau, Jr., P. and Samuels, George, The handling of sugarcane trash: I. Yields and economic considerations, *Jour. Agric. Univ. P. R.*, 1951.
7. Nelson, L. B. and Muckenhirn, R. J., Field percolation rates of four Wisconsin soils having different drainage characteristics, *Journ. Amer. Soc. Agron.* **33**(**11**) 1028–1036, 1941.
8. Owen, Wm. L., and Denson, W. P., The effect of plowing under cane trash upon the available nitrogen of the soil (from the Dept. of Bacteriology La. Expt. Sta.), *Zentralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten*, 11 Abteilung, Bd. 82, 1930.
9. Puerto Rico Bureau of Commerce, *Annual Book of Statistics of Puerto Rico*, Dept. of Agr. and Commerce, pp. 84–86, 1951.
10. Roberts, R. C., *Soil Survey of Puerto Rico*, U.S.D.A. in cooperation with Agr. Expt. Sta. Univ. of P. R., Series, 1936, No. 9, 1942.
11. Silva, E., and Serra, G., *Census of Sugarcane Varieties Grown in Puerto Rico for the 1949 Crop*, E. A. 11 Agric. Expt. Sta., Univ. of P. R., Feb. 1950.
12. Smith, R. M., Furhiman, D., and Silva, S., Simple procedures for studying soil cores collected with the Kelley (Utah) sampling machine, BPI-SCS *Cooperative Research Project Report* No. 181, 5 mimeographed pages, March 1, 1950.