

Molasses Distillery Slops Supply Nitrogen and Potassium Fertilizer to Flooded Rice^{1,2}

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ABSTRACT

Yields of four consecutive rice crops that received P fertilizer only increased with each increment of rum distillery slops, from an average of 2,033 kg of rough rice/ha when no slops were applied to 5,905 kg/ha when 240 hl of slops were applied/ha weekly for 12 weeks starting 2 weeks after planting. At this level of slops, a total of 215 kg of N and 475 kg of K were applied to each rice crop. Applying fertilizer N in addition to 160 hl of slops/ha weekly did not increase yields. Leaf contents of N, P, K, Ca, and Mg were not affected by the level of slops applied. Soil pH decreased with increasing levels of distillery slops. Exchangeable NH_3 content of the soil was not affected by the application of slops. Exchangeable and HNO_3 -extractable K increased with increasing levels of slops, from a total of 313 kg/ha when no slops were applied to 699 kg/ha when 240 hl of slops were applied/ha weekly for 12 weeks to four successive rice crops.

INTRODUCTION

About 1.6 billion liters of rum distillery slops is produced yearly in Puerto Rico, constituting a major disposal problem for the rum industry. The largest rum producer on the Island has spent \$15 million on a treatment plant for slops. Slops from molasses vary considerably in composition, averaging about 10% dry matter, which consists of the following range in composition percentages N = 1–2%, K = 2–4%, Mg = 1–3%, Ca = 2–3%, P = .03–.06% and organic matter = 91%.

Rosado and González (5) recently reviewed the literature on the use of slops as fertilizer. Innes (2) found that applying slops to sugarcane increased yields of sugar. Takata (7) found that diluted distillery slops were not harmful to rice plants and, at proper levels, increased yields. Pérez-Escolar and Lugo-López (4) found that slops increased yields of cut grasses. However, the use of slops as fertilizer is limited by the high cost of drying or transporting.

Puerto Rico is developing a modern rice industry on about 16,000 acres on the north coast, from San Juan, where the largest rum distillery on the island is located, to Arecibo, where the second largest distillery is established. Together, these distilleries produce about 1.2 billion liters of slops yearly.

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If slops are found to be an efficient source of N and K for rice, distribution in the field should be relatively simple. Slops could be pumped from the distilleries located at both extremes of the north coast rice growing area and injected into the main irrigation canals of each plain at the dosage found to be most desirable. From there, they would be distributed in the rice fields at no extra cost.

In a preliminary study, the authors found that applying 1,100 or 2,200 hl of slops/ha 3 weeks after planting increased rice yields by an average of 35 percent over those produced by nonfertilized rice and that dividing the 2,200/hl level into three equal biweekly applications increased yields by an additional 45%.

The experiments discussed in this paper were conducted to determine the effect of applying four levels of slops and of supplementary N applications, on yields of intensively managed rice for four successive crops over a 2-year period (1981-82) and on soil condition at the end of that period.

MATERIALS AND METHODS

The experiment was carried out at the Gurabo Substation at an elevation of about 80 m. Minimum and maximum temperatures are 19 and 31° C, respectively. Average annual rainfall is 1,450 mm. The soil is Coloso clay (Aeric Tropic Fluvaquent) with a pH of 7.0.

Plots were 3 × 3 m and were surrounded by earthen dikes. Each plot was connected directly by pipes to ditches so that it could be flooded or drained individually. A good seedbed was prepared, and 30 kg/ha of P was disced in. Seed of the Brazos, Nortai, or Mars varieties, as indicated, were planted at the rate of 120 kg/ha and covered lightly with soil. The plots were then irrigated by flooding them periodically as required. For weed control, Propanil was applied 3 weeks after planting. Then the plots were kept flooded to a depth of about 10 cm until 2 weeks before harvesting. Insects and diseases were controlled by spraying with appropriate pesticides as required. The rice was harvested when it contained about 20% moisture. Then it was cleaned and dried to 12% moisture.

At the prebloom stage of the third crop, samples of the third leaves were dried and analyzed for N by the Macro-Kjeldahl method; for K, by flame photometry; for P, by colorimetry; for Mn, by oxidation with potassium periodate; and for Ca and Mg, by the Versenate method.

After the experiment was concluded, the soil in all plots was sampled by taking 10 borings from 0- to 15-cm depths in each plot. The samples were air dried and passed through a 10-mesh screen. Exchangeable bases were extracted with normal neutral ammonium acetate, and exchangeable Ca and Mg were determined by the Versenate titration method (1).

Exchangeable K was determined by flame photometry and readily available K by extraction with HNO_3 . Exchangeable Al was extracted with normal KCl and determined by the double titration method (3). Soil reaction was measured with a glass electrode pH meter by the use of a saturated paste.

After four crops were grown, all plots were planted to rice without further applications of fertilizer or slops in order to determine the residual effects of the treatments on rice yields.

Treatments, replicated six times in a partially balanced block design, were as follows:

1. No N or K
2. 60 kg/ha each of N and K applied at planting and 45 days later
3. 80 hl of distillery slops/ha weekly for 12 weeks starting 2 weeks after planting
4. 160 hl distillery slops/ha weekly
5. 240 hl of distillery slops/ha weekly
6. 160 hl of slops/ha weekly + 60 kg of N/ha
7. 160 hl of slops/ha weekly + 120 kg of N/ha
8. 160 hl of slops/ha weekly + 240 kg of N/ha

RESULTS AND DISCUSSION

Yields from plots that received P only, increased with each increment in the levels of slops applied, from an average of 3,033 kg of rough rice/ha when no slops were applied to 5,905 kg/ha, a very high yield, when 240 hl slops were applied/ha weekly for 12 weeks, starting 2 weeks after planting (table 1).

Yields increased linearly with each increment in the level of slops applied (fig. 1). Considerably higher yields were produced during the dry season than during the wet season due to higher insolation rates during the dry season.

Applying fertilizer N in addition to 160 hl of slops weekly did not significantly increase yields above those obtained with the application of 240 hl of slops/ha weekly (table 1).

The leaf content of N, P, K, Ca, and Mg at the prebloom stage were not affected by the treatments (table 2).

Soil pH decreased as the level of slops applied increased, from 7.15 when no slops were applied to 6.3 when 240 hl was applied weekly. Increasing N rates also tended to decrease soil pH.

Exchangeable NH_3 in the soil was not affected by the treatments, indicating that the N applied was (a) taken up by the rice plants, (b) was lost through leaching or by volatilization, or (c) was not mineralized from organic form in the slops. Exchangeable Ca and Mg content of the soil was not appreciably affected by the level of slops or of N applied.

TABLE 1.—Effect of rum distillery slops and of fertilizer nitrogen on yields produced by four successive rice crops and a residual crop

Treatment	Yields of dry rough rice (kg/ha)				Average of four crops	Residual ¹ crop
	I Brazos variety planted 2/24/81	II Brazos variety planted 9/17/81	III Nortai variety planted 2/10/82	IV Mars variety planted 8/24/82		V Mars variety planted 3/21/83
No N, K or slops	3,880	2,930	2,900	2,420	3,033 d ²	3,070 c,d
60 kg of N and K/ha at planting and 45 days later	5,670	4,020	5,080	4,230	4,750 b	2,640 d
80 hl of slops/ha weekly ³	5,130	3,680	4,230	2,770	3,953 c	3,480 b,c
160 hl of slops/ha weekly	6,420	4,720	5,120	3,190	4,873 b	3,790 a,b
240 hl of slops/ha weekly	7,440	5,420	6,470	4,290	5,905 a	4,560 a
160 hl of slops/ha weekly + 60 kg of N/ha ⁴	7,760	5,380	6,370	4,350	5,965 a	4,020 a,b
160 hl of slops/ha weekly + 120 kg of N/ha	8,040	5,530	6,430	4,830	6,208 a	4,010 a,b
160 hl of slops/ha weekly + 240 kg of N/ha	7,810	4,990	7,890	4,450	6,285 a	4,290 a

¹ Received no fertilizer or slops.

² Values followed by the same letters do not differ significantly at the 5% level.

³ For 12 weeks, starting 2 weeks after planting.

⁴ All N applied in two equal applications, one at planting and one 6 weeks later.

Exchangeable K increased with increasing levels of slops, from 46 kg/ha when none was applied to 161 kg/ha when the highest level was applied, whereas HNO_3 -soluble K increased from 267 kg/ha when none was applied to 538 kg/ha when the highest level was applied.

At the optimum level of slops (240 hl/ha weekly for 12 weeks), 288,000 L would be applied per crop and the slops would contain 235 kg of N and 475 of K/ha.

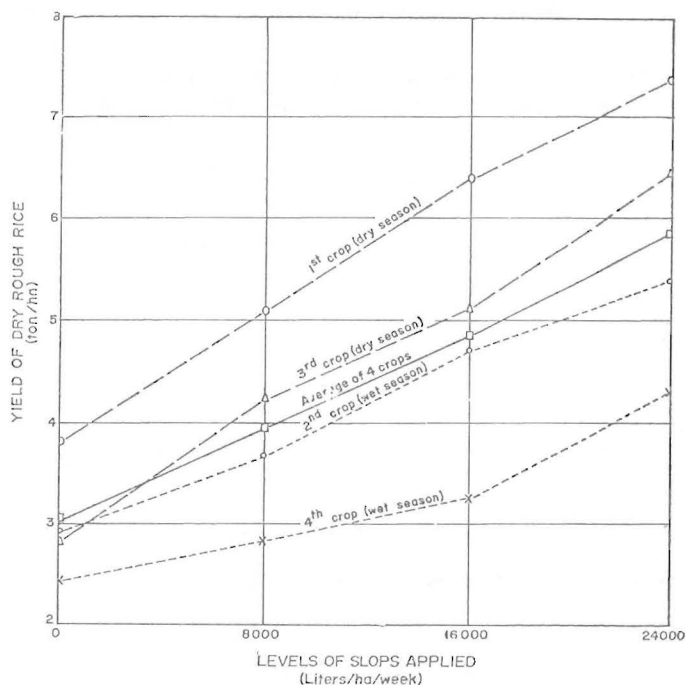


FIG. 1.—Effect of levels of slops applied on yields of four successive rice crops receiving no nitrogen or potassium fertilizer.

On the basis of the data obtained by Silva and Vicente-Chandler (6) under conditions similar to those in these experiments, in these four crops a total of about 550 kg of N/ha was taken up by high yielding rice plants. Thus, with the highest level of slops, about 59% of the 936 kg of N/ha applied (table 3) was taken up by the rice plants. This level of N recovery by the rice plants was similar to that usually obtained under very good conditions.

Applications of slops to four successive rice crops had a strong residual effect on yields of a subsequently planted rice crop receiving no fertilizer

or slops (table 1). Yields increased from 3,070 kg of rough rice/ha produced by plots which had previously received neither N nor slops, to 3,480, 3,790 and 4,560 kg/ha from plot receiving 80, 160 and 240 hl of slops/ha weekly during the preceding four crops, respectively. Fertilizer N had no significant residual effect on rice yields except at the 240 kg/ha rate.

Slops as applied in this experiment, therefore, appear to be an efficient source of N, which is apparently available gradually and at a rather uniform rate throughout the cropping period and, after several crops, beyond this period.

At the highest level of slops, 2,068 kg of K/ha was applied, of which 386 accumulated in the soil as exchangeable or HNO_3 = soluble K (table

TABLE 2.—*Effect of levels of distillery slops and nitrogen fertilization on leaf composition of rice at the prebloom stage*

Treatment	Dry weight composition of leaves (%)				
	N	P	K	Ca	Mg
No N, K or slops	2.43	.22	1.52	.39	.27
60 kg of N and K/ha at planting and 45 days later	2.12	.23	1.62	.36	.24
80 hl of slops/ha weekly ¹	2.52	.23	1.66	.38	.23
160 hl of slops/ha weekly	2.00	.25	1.60	.37	.21
240 hl of slops/ha weekly	2.07	.25	1.69	.37	.21
160 hl of slops/ha weekly + 60 kg of N/ha ²	2.41	.24	1.62	.37	.23
160 hl of slops/ha weekly + 120 kg of N/ha	2.32	.24	1.58	.38	.20
160 hl of slops/ha weekly + 240 kg of N/ha	2.45	.22	1.56	.35	.23

¹ For 12 weeks, starting 2 weeks after planting.

² All N applied in two equal applications, one at planting and one 6 weeks later.

3), about 750 kg was taken up by the crop, and the remainder was apparently leached into the soil below the depths sampled.

The quantities of salts applied in the levels of slops used in this experiment should not constitute a problem with flooded rice when irrigation water is low in salts. At the highest level of slops, 240 hl/ha weekly for 12 weeks for each of two crops, a total of about 4,000 kg of salts (K, Mg, Ca, Na) would be applied/ha yearly. As noted, pH of the soil decreased with increasing levels of slops and only 386 kg/ha of the 2,068 kg/ha of K applied to the four rice crops accumulated in the soil.

The possible accumulation of organic matter in the soil would be considered a favorable aspect of slops applications. A total of about 50,000 kg/ha of organic matter would be added to the soil yearly with

TABLE 3.—*Effect of levels of distillery slops and nitrogen fertilization on soil condition after four successive rice crops*

Treatment	pH	Exchangeable Ca	Exchangeable Mg	Exchangeable NH ₃	Total N applied	Exchangeable K	HNO ₃ - soluble K	Exchangeable + HNO ₃ soluble K	Total K applied
		<i>me/100 g</i>	<i>me/100 g</i>	<i>kg/ha</i>	<i>kg/ha</i>	<i>kg/ha</i>	<i>kg/ha</i>	<i>kg/ha</i>	<i>kg/ha</i>
No N, K or slops	7.15	11.0	11.5	234	0	46	267	313	0
60 kg of N and K/ha at planting and 45 days later	7.05	10.9	10.4	234	480	28	194	222	328
80 hl of slops/ha weekly ¹	6.95	10.5	11.2	184	312	77	339	416	688
160 hl of slops/ha weekly	6.75	10.0	9.1	230	624	110	473	583	1,376
240 hl of slops/ha weekly	6.30	9.3	9.3	260	936	161	538	699	2,068
160 hl of slops/ha weekly + 60 kg of N/ha ²	6.75	9.7	9.5	202	864	119	439	558	1,376
160 hl of slops/ha weekly + 120 kg of N/ha	6.60	9.9	9.7	230	1,104	109	428	537	1,376
160 hl of slops/ha weekly + 240 kg of N/ha	6.50	9.5	10.9	220	1,584	116	457	573	1,376

¹ 75 kg of N and 165 kg of K/1000 hl of slops.

² In two equal applications, one at planting and one 45 days later.

two crops at the maximum application rates. However, the slops produced by the largest distillery is treated to remove most of the organic matter but still retains almost all of the N and K.

On the basis of the results of these experiments, two crops of rice yearly would require a total of about 5,760 hl of slops/ha. Thus the 12 million hl of slops produced yearly by the north coast distilleries could supply all of the fertilizer required by 2,100 ha (5,200 acres) of rice. If rum production were doubled, as is predicted over the next decade, slops could provide all of the N and K required by about 10,000 acres of rice.

When slops are used as the sole source of N and K for rice, they substitute for fertilizer valued at about \$250/ha (\$100/acre) yearly with two crops per year. Slops from the distillery located at Arecibo would have to be pumped only a few kilometers to the main irrigation canal for the Arecibo river lowland, but those from the San Juan distillery would have to be pumped about 25 km to the Toa Baja and Vega Baja area.

RESUMEN

La industria de ron de Puerto Rico produce alrededor de 16,000 millones de hectolitros de mosto (flema) al año, mayormente cerca de la región en que se está estableciendo la industria arrocera.

Se realizaron cuatro siembras consecutivas de arroz en las mismas parcelas para comparar el efecto de distintos niveles de mosto y de nitrógeno sobre la producción y composición foliar del arroz y en la condición del suelo.

La producción de arroz aumentó con cada incremento de mosto de un promedio de 3,033 kg de arroz seco en cáscara por hectárea cuando no se aplicó mosto a 5,905 kg/ha cuando se aplicaron 240 hl de mosto por hectárea por semana y durante 12 semanas, empezando 2 semanas después de sembrarlo.

Esta cantidad de mosto contiene un total de 215 kg de nitrógeno y 475 kg de potasio por hectárea y cosecha.

La aplicación de nitrógeno en adición a 160 hectolitros de mosto por hectárea por semana no aumentó la producción sobre la obtenida mediante la aplicación de 240 hectolitros de mosto por hectárea y semana.

La aplicación de mosto no afectó el contenido en N, P, K, Ca y Mg de las hojas.

El pH del suelo disminuyó según se aumentó el nivel de mosto de 7.15 cuando no se aplicó mosto a 6.3 cuando se aplicaron 240 hl. de mosto por hectárea y semana. Los tratamientos no afectaron el contenido en amonio cambiante en el suelo.

Tanto el potasio cambiante en el suelo como el extraído con ácido nítrico aumentaron según aumentó la aplicación de mosto. Al finalizar las cuatro

cosechas, el total de ambos aumentó de 313 kg de potasio por hectárea cuando no se aplicó mosto, a 699 kg/ha cuando se aplicaron 240 hectolitros de mosto por hectárea y semana. La cantidad de calcio y magnesio cambiante en el suelo no se afectó con la aplicación de mosto.

Estos datos señalan que el mosto es una buena fuente de nitrógeno y de potasio para la producción de arroz. El mosto que se produce actualmente en la costa norte es suficiente para suplir todo el nitrógeno y el potasio para 2,100 ha (5,208 cuerdas) de arroz que puede distribuirse en el agua de riego.

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