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The Efficiency of Sugarcane in its Use of Nitrogen Fertilizer Applications

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INTRODUCTION

Anyone associated with the growing of sugarcane knows that nitrogen fertilizers are needed for the maintenance of optimum production. Nitrogenous fertilizers are used in all sugarcane-growing areas of the world. The amounts and sources vary with area, soil, climate, and customs. The tendency in many of the leading cane-growing areas is to use higher levels of nitrogen than were used many years ago. Technical advances such as foliar diagnosis, aerial application, and usage of gaseous and liquid nitrogen sources, have all led to cheaper, wiser, and more effective utilization of the nitrogen applied to sugarcane.

Nevertheless, we lack many criteria by which to judge just how efficiently these nitrogen applications are being used by the growing cane. When we consider that nitrogen is being applied to cane in humid and irrigated areas at various rates, on plant crops and ratoons harvested at different ages with varying yields, we begin to wonder just how effective each pound is under these involved crop relationships. At present, the best criterion we have to judge nitrogen efficiency is to evaluate the yields produced by sugarcane when the element is applied. Unfortunately, the evaluation of the effectiveness of nitrogen applications on cane has been limited to random field observations by the growers. No study has been made to determine the efficiency of nitrogen under the varied crop relationships of Puerto Rico.

Many practical questions could be answered by a study of the efficiency with which nitrogen is used by growing sugarcane. Here are but a few that need answers:

Do plant canes or ratoons make more efficient use of the nitrogen applied? Does the efficiency of the applied nitrogen decrease as the application rate increases? Which uses applied nitrogen more effectively, cane grown in humid or in irrigated areas? Does sugar production suffer at high nitrogen-

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application rates? How many pounds of applied nitrogen does it take to produce a ton of cane or a ton of sugar?

PROCEDURES

Data from the sugarcane-fertilizer field experiments conducted by the Agronomy and Horticulture Department of the Agricultural Experiment Station of the University of Puerto Rico, for the period 1938–54, were utilized in order to answer some of these and other questions concerning nitrogen efficiency in fertilizing sugarcane. These experiments include 127 tests with 12 cane varieties and 9 soil types, and represent all major cane-producing areas of Puerto Rico. Data were selected from such of these tests as were associated with the specific nitrogen treatment that produced the highest sugar yields: that is to say, the quantity of nitrogen added per acre to produce the maximum proved response, statistically significant at least at the 5-percent level, in tons of available 96° sugar per acre. The data for the no-nitrogen application were used in those cases were no significant response was obtained from nitrogen. All experiments were replicated at least six times, the majority having nine replications per fertilizer treatment. Ammonium sulfate (20-percent nitrogen) was the nitrogen source used in all cases, and sufficient phosphate and potash were added to all nitrogen treatments so that these two elements were not limiting factors in the study of the nitrogen levels.

RESULTS

The results of the efficiency of sugarcane in its use of nitrogen have been arranged according to such specific factors as type of crop, water supply, pounds of nitrogen applied per acre, and tons of sugar produced per acre per month. The efficiency of sugarcane in utilizing the applied nitrogen is then discussed under these headings.

TYPE OF CROP

It is evident from the data presented in table 1 that fall and spring plantings were more efficient users of nitrogen than the ratoon crops. The plant cane required less nitrogen per acre, per month, and per ton of cane and of sugar to produce as much sugar per month (TSAM) as the ratoons.

The nitrogen needed per acre was lowest for the spring plantings at 109 pounds, and highest for the ratoons, at 140. On the basis of the nitrogen used per month of cane growth, fall plantings were the most efficient nitrogen users, requiring 7.2 pounds of nitrogen per month. The spring plantings were somewhat less efficient, needing 2.2 pounds more of nitrogen per acre, and the ratoon crops were the least efficient users of nitrogen, needing 4 pounds more nitrogen per month than fall plantings for optimum sugar

TABLE 1.—*Influence of the type of crop on the nitrogen efficiency of sugarcane*

Crop	Tests	Age at harvest	Amount of nitrogen per—				Yields per acre of—			
			Acre	Month	Ton of cane	Ton of sugar	Cane	Sugar	Cane per month (TCAM)	Sugar per month (TSAM)
	Number	*Months*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*	*Tons*
Fall planting (Gran Cultura)	25	17.3	125	7.2	2.0	16.7	61.4	7.5	3.6	0.43
Spring planting (Primavera)	13	11.6	109	9.4	2.4	20.1	46.4	5.4	4.0	.47
Ratoons	89	12.5	140	11.2	3.3	25.8	42.4	5.4	3.4	.43
Weighted means		13.4	138	9.8	3.0	23.2	46.1	5.8	3.4	0.43

yields. When we translate this into pounds of nitrogen applied per ton of cane produced, we still find the fall planting more efficient than the ratoon crops. The latter needed 1.3 pounds of nitrogen more per ton of cane produced than did the former. The same trend held in terms of nitrogen used per ton of sugar produced.

When we consider the yields per acre of cane and sugar the fall plantings with a longer growing season outproduced both the spring plantings and the ratoons. However, when we equalize these crops on a basis of growth per month, both for tons of cane and sugar, we find very little difference between any of them. Thus we find that, although on a basis of growth per month, our three types of cane crop were about equal in cane and sugar production, the fall plantings were the most efficient in their use of applied nitrogen, followed by spring plantings and ratoons in that order.

Why do plant canes require less applied nitrogen for efficient sugar production that do ratoons? The reason for their more efficient use of applied nitrogen may be that the plant canes have a better supply of reserve nitrogen in the soil to use than do ratoons. This larger supply of nitrogen for the plant canes comes from the large quantities of organic materials, such as old roots and cane trash, which were incorporated into the soil when the land was prepared for planting (2).[2] The ratoon lacks this large quantity of rapidly decaying organic materials. Therefore, this larger reserve of nitrogen made available to the plant canes means that less applied nitrogen is needed for the cane to produce optimum yields. Probably the sum total of nitrogen used per acre and per ton of cane is the same for plant crops and ratoons. The higher efficiency of nitrogen used by the plant canes is limited to ap-

[2] Numbers in parentheses refer to Literature Cited, p. 217.

TABLE 2.—*Influence of the water supply on the nitrogen efficiency of sugarcane*

Region in which plantings were located	Tests	Quantities of nitrogen needed per—				Yields per acre of—			
		Acre	Month	Ton of cane	Ton of sugar	Cane	Sugar	Cane per month (TCAM)	Sugar per month (TSAM)
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*	*Tons*
Humid	61	171	12.4	3.4	26.3	50.3	6.33	4.7	0.47
Semi-irrigated	39	127	9.0	3.4	26.5	37.3	4.79	2.9	.38
Irrigated	15	87	5.9	1.5	12.9	43.2	6.75	3.9	.47
Semiarid	12	53	3.5	1.3	10.2	40.7	5.39	3.0	.39
Weighted means		138	9.8	3.0	23.2	46.1	5.82	3.4	0.43

plied nitrogen only. The sugar-grower is obliged to increase his rate of nitrogen application for ratoons only because there is less reserve nitrogen in the soil for the ratoons to draw upon.

WATER SUPPLY

The cane grown in Puerto Rico is exposed to a variety of regional differences in water supply, ranging from humid to semiarid conditions. Canes growing under humid conditions where rainfall is adequate throughout the year for good growth (60–95 inches) used more nitrogen per acre than those grown under any other conditions (table 2). The other groups followed a descending order in nitrogen used per acre in reference to the water available as natural rainfall, ranging from semi-irrigated, to irrigated, to semiarid, the lowest nitrogen user per acre. The use of nitrogen per month, per ton of cane, and per ton of sugar also followed this order, with cane grown in humid areas using more nitrogen for optimum production, and that grown under semiarid conditions using the least.

When we consider yields per acre of cane, the humid area was highest with the irrigated second. However, irrigated cane stood first in tons of sugar per acre, with cane from the humid area close behind. Cane from semiarid areas produced better than that from semi-irrigated areas. On a per month basis, the humid area produced almost 1 ton of cane more than did the irrigated, but the irrigated cane's higher sucrose gave it equal ranking in reference to sugar produced per month. The humid-area cane thus used twice as much nitrogen in order to produce about the same amount of sugar per acre as the irrigated cane. In other words, irrigated cane is twice as efficient as humid-area cane in using the nitrogen applied. Also semiarid-grown cane (all experiments located at the Lajas Substation), under the conditions of these trials, proved to be over twice as efficient in nitrogen use as the semi-irrigated cane (all experiments located in the Isabela area).

TABLE 3.—*Influence of tons of sugar produced per acre per month (TSAM) on the nitrogen efficiency of sugarcane plant canes and ratoons*

Sugar per month (tons) (TSAM)	Mean sugar produced per month	Tests	Age at harvest	Amounts of nitrogen per—				Yields per acre of—		
				Acre	Month	Tons of cane	Tons of sugar	Cane	Sugar	Cane per month (TCAM)
Plant canes										
	Tons	*Number*	*Months*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*
Under 0.30	0.29	2	17.2	50	3.0	1.2	10.0	41.5	5.0	2.1
0.30–.39	.36	7	15.8	125	7.0	2.4	19.1	47.5	5.6	3.0
.40–.49	.44	16	14.4	117	8.1	2.0	18.5	54.1	6.3	3.8
.50–.59	.53	6	14.4	160	11.9	3.1	23.2	58.9	7.6	4.2
Over .60	.65	4	16.0	198	12.5	2.4	19.1	81.6	10.4	5.1
Ratoons										
Under 0.30	0.23	9	13.2	132	10.3	5.4	46.6	26.5	3.1	2.1
.30–.39	.35	18	12.4	99	8.1	3.1	24.0	32.9	4.3	2.5
.40–.49	.43	33	12.5	125	10.0	2.7	23.2	42.7	5.4	3.4
.50–.59	.53	25	12.7	154	12.3	3.1	23.0	51.0	6.7	4.0
Over .60	.61	4	12.2	175	14.4	3.3	23.7	55.4	7.5	4.6

TONS OF SUGAR PER ACRE PER MONTH

The best measure of sugar production from the field standpoint is the yield in tons of sugar per acre per month. This criterion takes into consideration cane-tonnage yields, sucrose-percent-cane, and age of crop. It allows for comparison regardless of the age of the crop. In order to see how nitrogen applications were utilized by the cane in producing tons of sugar per acre per month (TSAM), the values were classified into groups and the results are given in table 3.

Both for plant canes and ratoons there was a generalized increase in pounds of nitrogen per acre necessary for increasing the tons of sugar per acre per month, which means that more applied nitrogen was needed to produce more sugar. This is shown graphically in figure 1. We find that there were no appreciable differences in the quantities of nitrogen applied per ton of cane produced for any of the classes of TSAM, aside from the under-0.30 TSAM class. In other words, the same quantity of nitrogen was needed per ton of cane (2.5 pounds for plant canes, 3.1 for ratoons) for low sugar production per acre per month as for high. Therefore, it appears that cane utilizes applied nitrogen with the same efficiency at low or high rates of application per acre, the only difference being that more sugar per acre

per month is produced at the higher rates. Of course, it should be remembered that the rates of nitrogen used were up to 198 pounds per acre. Nitrogen additions above this rate would not be expected to show the same efficiency because of the law of diminishing returns.

A point often raised when speaking of nitrogen applications at various rates is the influence the nitrogen applied may have on sucrose production. If we plot the tons of cane per acre per month against the tons of sugar produced per acre per month, we obtain a highly significant linear relationship. The rise in cane tonnage was linear with increases in sugar, inasmuch as the sucrose-percent-cane tended to remain steady at all levels of tonnage production. Thus increased cane tonnage, due in part to higher levels of

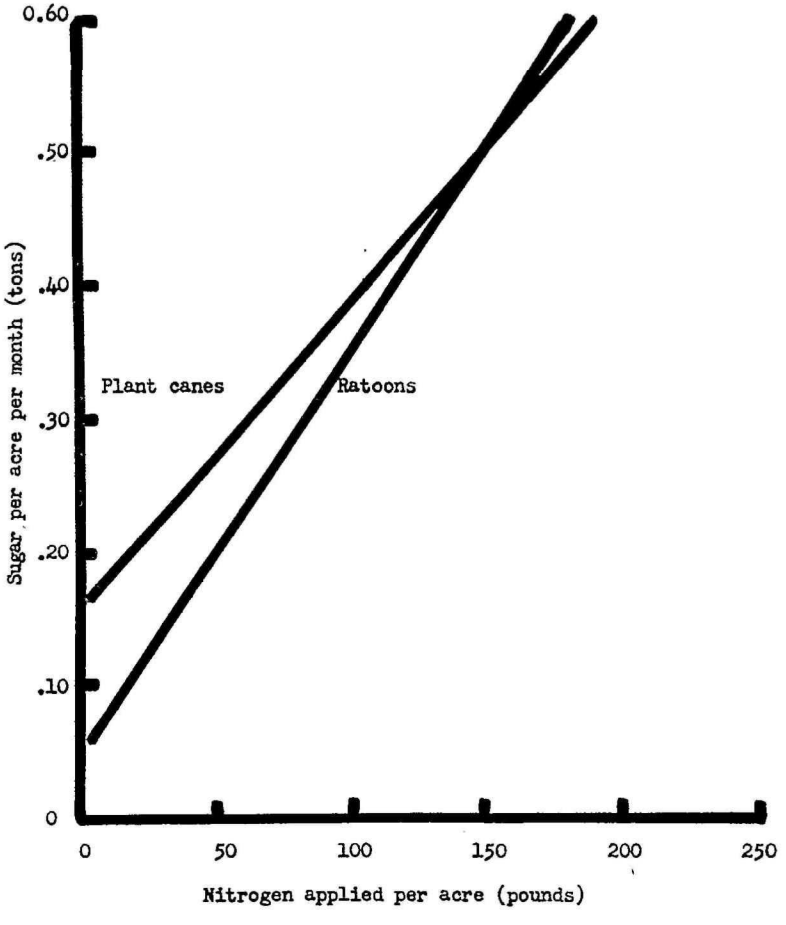

FIG. 1.—The influence of applied nitrogen on the production of sugar per acre per month by plant canes and ratoons.

TABLE 4.—*A comparison of the nitrogen efficiency of sugarcane producing over 0.50 ton of cane per acre per month in Hawaii and in Puerto Rico*

Location	Crop	Age at harvest	Amount of nitrogen used per			
			Acre	Month	Ton of cane	Ton of Sugar
		Months	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Hawaii	Plant cane	20.9	173	8.3	1.7	14.6
	Ratoon	18.8	175	9.6	2.1	17.4
Puerto Rico	Plant cane	16.0	175	12.1	2.8	21.6
	Ratoon	12.2	157	12.6	3.1	23.1

nitrogen application, did not show any tendency to lower sucrose values at the higher tonnage levels.

If we consider the production of 0.50 ton and over of available 96° sugar per acre per month as excellent production, we see that plant crops required a range of 160 to 198 pounds of nitrogen per acre, and ratoons 154 to 175 pounds. An average of 12 pounds of nitrogen per acre was used to produce over 0.50 ton of sugar per acre per month. In terms of tons of cane, this production of over 0.50 ton of sugar required about 3 pounds of nitrogen per ton of cane; in terms of sugar, the figure was about 23 pounds of nitrogen per ton of sugar.

Borden (1) determined the nitrogen efficiency of sugarcane growing in Hawaii. An interesting comparison of data from his cane producing over 0.50 ton of sugar per acre per month and the data from Puerto Rico is presented in table 4. We see that about the same amount of nitrogen per acre was needed in both islands, except that Puerto Rican ratoons, aged about 6 months less than Hawaiian, required about 20 pounds of nitrogen less.

Hawaiian cane used 5 pounds less of nitrogen per month. Hawaiian plant canes and ratoons used 1 pound of nitrogen less per ton of cane. There was more efficient nitrogen use with plant canes than with ratoons in both cane areas. Hawaiian cane needed 6 pounds less nitrogen than Puerto Rican cane per ton of sugar. Therefore, Hawaiian and Puerto Rican cane required about the same amounts of nitrogen per acre for optimum sugar yields, but Hawaiian cane used nitrogen a bit more efficiently and required about 3 pounds less per month or 1 pound less per ton of cane.

SUMMARY

The efficiency of sugarcane in using applied nitrogen was evaluated for 127 fertilizer tests. The evaluation was based on selected Station data which were associated with specific nitrogen treatments that produced the optimum sugar yield. The results obtained were as follows:

1. The fall and spring plantings were more efficient users of nitrogen than were ratoon canes.

2. Canes in humid areas were less efficient users of applied nitrogen than those in irrigated areas. Canes in semiarid areas used less nitrogen than did those in semi-irrigated areas.

3. There was an increase in tons of sugar per acre per month with increases in the nitrogen applied per acre.

4. The cane used about the same amount of applied nitrogen per ton of cane produced at either low or high rates of sugar production per acre per month.

5. Yields of tons of sugar per acre per month showed an excellent positive linear relationship with tons of cane per acre per month. The increase in cane tonnage did not show any tendency to lower sucrose values at the higher cane tonnages.

6. Taking the production of over 0.50 ton of sugar per acre per month as a criterion of very good sugar yields, this required an average of 3 pounds of nitrogen per ton of cane and 23 pounds per ton of sugar.

7. When cane nitrogen efficiency in Puerto Rico and Hawaii in producing over 0.50 ton of sugar per acre per month was compared it was found that both required about the same rates of nitrogen per acre, but in Hawaii the cane used 3 pounds less nitrogen per month, 1 pound less nitrogen per ton of cane, and 6 pounds less nitrogen per ton of sugar than Puerto Rico.

RESUMEN

La eficiencia del uso del nitrógeno para abonar la caña de azúcar se evaluó tomando en consideración los resultados de 127 experimentos de abonamiento. Esta evaluación se basó en aquellos datos en los cuales el tratamiento específico con nitrógeno estaba asociado con el rendimiento óptimo de la caña.

Los resultados que se obtuvieron fueron los siguientes:

1. Las siembras de otoño y de primavera usaron el nitrógeno más eficientemente que los retoños.

2. Las cañas de las áreas húmedas no usaron el nitrógeno tan eficientemente como las de las áreas bajo riego. Las cañas de las áreas semiáridas usaron menos nitrógeno que las de las áreas en donde se usaba el riego a media capacidad.

3. En cuanto a las toneladas de azúcar producidas por mes, hubo un aumento general en el uso de libras de nitrógeno por acre, para asímismo aumentar el número de toneladas de azúcar por mes.

4. Irrespectivamente de que la producción de azúcar por acre por mes fué baja o alta, la caña usó casi la misma cantidad de nitrógeno aplicado por tonelada de caña producida.

5. Los rendimientos de azúcar por acre por mes, demostraron una relación positiva linear excelente con el número de toneladas de caña pro-

ducido por acre por mes. El aumento en el tonelaje no demostró tendencia alguna a bajar los valores de sacarosa en la caña, aún en las producciónes más altas.

6. Cuando se tomó como criterio una producción sobre 0.50 toneladas de azúcar por acre por mes, se requirieron 3 libras de nitrógeno por tonelada de caña producida y 23 libras por tonelada de azúcar.

7. Cuando se comparó la eficiencia para producir sobre 0.50 toneladas de azúcar por acre por mes, entre Puerto Rico y Hawaii, en ambos países la caña necesitó casi igual proporción de nitrógeno por acre, pero en Hawaii se usaron 3 libras menos de nitrógeno por mes, una libra menos por tonelada de caña y 6 libras menos por tonelada de azúcar que en Puerto Rico.

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