Rev. Fac. Agron. (LUZ). 2000, 17: 318-326

Effects of vinasse on sugarcane (*Saccharum officinarum*) productivity[1]

Efecto de la vinasa en la productividad de la caña de azúcar (*Saccharum officinarum*)

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Abstract

Vinasse is a corrosive and contaminant industrial liquid residue from alcohol distillation. Vinasse contains high levels of organic matter, potassium, calcium and moderate amounts of nitrogen and phosphorus. The effects of several applications of mineral fertilization combined with vinasse on sugarcane productivity were evaluated, on plant-cane, first and second ratoon seasons (92-95). The experiment was established using a randomized split plot design with four replications. Treatments consisted of 3 chemical fertilizer doses in the main plots as: F0= 0 kg ha^{-1}; F1= 180 kg ha^{-1} N + 160 kg.ha^{-1} P_2O_5 + 220 kg ha^{-1} K_2O; F3= 80 kg ha^{-1} N + 45 kg.ha^{-1} P_2O_5 combined with 5 vinasse doses in the subplots as V0=0 m^3.ha^{-1}, V1=25 m^3.ha^{-1}, V2=50 m^3.ha^{-1}, V3=75 m^3.ha^{-1} and V4=100 m^3 ha^{-1}. Sugar and cane yields increased with application of vinasse. Best results were obtained when using vinasse as 50 m^3 ha^{-1} on plant-cane and 100 m^3 ha^{-1} on first and second ratoons. The N, P_2O_5 and K_2O sugarcane demands were supplied by the 50 m^3 ha^{-1} vinasse dose (V2) in proportions of 55%, 72% and 100% respectively. Vinasse application demonstrated its efficiency as fertilizer material as well as reducing vinasse contaminant effects to waterways.

Key words: contaminants, fertilizer, nutrients, yield, sugarcane, vinasse.

Resumen

La vinasa es un residuo industrial líquido de la destilación del alcohol, altamente corrosivo y contaminante. La vinasa contiene elevados niveles de potasio, calcio y materia orgánica disuelta, así como niveles medios de nitrógeno y fósforo. En este trabajo realizado durante los años 92-95 en plantilla, primera y segunda soca de caña de azúcar, se estudiaron los efectos de la aplicación de varias dosis de vinasa en combinación con la fertilización mineral, sobre la productividad del cultivo. Se utilizó un diseño experimental completamente aleatorizado en parcelas divididas, con cuatro repeticiones. Los tratamientos fueron tres niveles de

Recibido el 18-10-1999 ● Aceptado el 20-3-2001

1. Financiamiento por CDCHT-UCLA y convenio CONICIT-UCLA F-57

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fertilización mineral (F0= 0 kg ha^{-1}; F1= 180 kg ha^{-1} N + 160 kg ha^{-1} P_2O_5 + 220 kg ha^{-1} K_2O; F3= 80 kg.ha^{-1} N + 45 kg ha^{-1} P_2O_5 combinados con cinco niveles de vinasa en las sub-parcelas, V0=0 m^3 ha^{-1}, V1=25 m^3.ha^{-1}, V2=50 m^3 ha^{-1}, V2=75 m^3 ha^{-1}, V5=100 m^3 ha^{-1}. El rendimiento en azúcar y en caña fue incrementado con la aplicación de la vinasa. Los mejores resultados fueron obtenidos con la aplicación de vinasa a niveles de 50 m^3 ha^{-1} en plantilla y de 100 m^3 ha^{-1} en primera y segunda soca. Los resultados demuestran que las demandas de N, P_2O_5 y K_2O de la caña de azúcar, fueron suministradas por la dosis de 50 m^3 ha^{-1} de vinasa, en proporción de 55 %, 72 % y 100 %, respectivamente. Los resultados de la aplicación de vinasa demostraron su eficacia como material fertilizante y la reducción de su efecto contaminante a las vías de agua.

Palabras clave: contaminantes, fertilizantes, nutrientes, rendimiento, caña de azucar, vinasa.

Introduction

One of the factors affecting sugarcane productivity is fertilization. However, mineral fertilizers have significantly increased their prices. As a result, it has become necessary to seek alternatives that would supply the soil with more economic nutrients.

The Turbio river plain in Lara state, Venezuela, is an important sugarcane production area (4). Several sugarcane alcohol distilleries are located in Lara state. Vinasse is a by-product of distilleries during alcohol production. In terms of volume, approximately 13 L of vinasse are produced by each L of alcohol obtained from cane must (3). Vinasse is a residue highly corrosive and contaminant to water sources (2, 3). According information (personal communications) of the Department of Environmental Control of *Licorerias Unidas S.A.* and the Department of Quality Control of *Alcoholes Occidente C.A.*, two local distilleries, they respectively produce around 1.000.000 and 700.000 L by day of vinasse, which disposition is a locally relevant affair.

Vinasse has high levels of potassium, calcium and organic matter in its chemical composition as well as moderate amounts of nitrogen and phosphorus (5) and could represent an alternative to supply such nutrients in crop production (4, 5).

Various research works carried out in other countries, particularly in Brazil, report that vinasse increases sugarcane productivity (2, 3, 5, 7) as well as they have demostrated that under controlled conditions, it can partially or completely replace mineral fertilization.

Current reports of vinasse research come from regions with different topography, climate and soil conditions to the areas where sugarcane is cultivated in Venezuela, so those experiences cannot be directly extrapolated to our conditions (2, 4, 6, 7, 9, 10). It is therefore necessary to adapt the technology of using vinasse in sugarcane production to the Turbio river plain conditions, by setting up research that determines the effects of vinasse as a fertilizer in sugarcane cultivation.

The former statements constitute the general framework of the current work. So the objectives of this work are:

1. To compare the use of vinasse as a fertilizer source versus a conventional mineral fertilizer application in a soil of the Turbio river valley.

2. To determine the effect of application of different doses of vinasse on yield and quality of the sugarcane crop in a soil of the Turbio river valley.

Materials and methods

This work was carried out as a three years field experiment (plant-cane, first ratoon and second ratoon), from 1992 to 1995, on a representative soil of the Turbio river plain sugarcane producing area in Lara state, Venezuela. According the Soil Taxonomy system of soil classification, the soil is a Fluventic Ustropept with the following properties; clay loam texture; moderately alkaline pH (7,4); moderately high salinity with EC (1:2) of 1,9 dS m^{-1}; low value of organic matter (3,1 %); moderately high CEC (23 cmol kg^{-1}); low P content (6 mg kg^{-1}); high Ca content (22.187 mg kg^{-1}); medium Mg content (343 mg kg^{-1}); low K content (46 mg kg^{-1}); good external and internal drainage (6).

A PR 980 sugarcane variety was used for the experiment. The experimental design used was a completely randomized with 4 replications. The treatment design was a split plot where 3 levels of chemical fertilizers (F) were assigned to the main plots and 5 levels of vinasse (V) were assigned to the subplots.

The doses of chemical fertilizer used were as follows:

FO= No chemical fertilizer use.

F1= 180 kg ha^{-1} of N + 160 kg ha^{-1} P_2O_5 + 220 kg ha^{-1} K_2O. These are the amounts of fertilizer usually applied in the area.

F2 = Complementary fertilization, using 80 kg ha^{-1} of N + 45 kg ha^{-1} of P_2O_5.

The following doses of vinasse were applied in the subplots as:

VO=0 m^3 ha^{-1}

V1=25 m^3 ha^{-1}

V2=50 m^3 ha^{-1}

V3=75 m^3 ha^{-1}

V4=100 m^3 ha^{-1}

For the first, second and third growing cycles (plant-cane, first ratoon and second ratoon, respectively), N and K doses were divided in two applications, half at the beginning and 45 days later, the other half. All P was applied at the beginning of each cycle. For plant-cane, first ratoon and second ratoon respectively, the dose of vinasse was divided in two applications, half 10 days after beginning the cycle and the other half, 45 days after the first application.

The vinasse was manually applied using 20 L plastic containers. The crop was irrigated the day after the application of vinasse.

Vinasse from a local distillery was used and analysis of N, P, K, Ca, Mg, pH and organic matter were performed according American Society for Testing and Materials (1) Vinasse analysis reports are the following: N (2 kg m^{-3}); P_2O_5 (2,3 kg m^{-3}); K_2O (7,5 kg m^{-3}), pH (4,2); organic matter (98,1 %).

Twenty stalks of the two central rows of each subplot were randomly harvested and weighed immediately. Sugar concentration was determined in sub samples taken from the biomass harvested in each plot. The results obtained are expressed in mg ha^{-1} of cane and in mg ha^{-1} of sugar.

Data were analyzed for significant differences using a split-plot analysis of variance and Duncan multiple range tests were used to separate means.

Results and discussion

The average yield of cane per ha for the different treatments are presented in table 1. There, it could be observed that for plant-cane, in the treatments where no chemical fertilizers are added (F0V0, F0V1, F0V2, F0V3, F0V4), a successive increase in cane yield is obtained with the successive increases in vinasse application. For first and second ratoon, the increase in yield also occurs with the application of vinasse as compared with its no application. The application of 100 m^3 ha^{-1} (F0V4), increased cane yield in 27 % for plant-cane, 23 % in first ratoon and 65 % in second ratoon in relationship with the treatment F0V0.

Variance analysis performed to these data showed that for cane yield on plant-cane, there were statistic high significant differences (1%) for vinasse application (V) and statistic significant differences (5%) for the interaction between the chemical fertilizer and vinasse (FxV). For the first ratoon, there were significant statistic differences for the chemical fertilizer (F), for vinasse (V) and for the interaction between the chemical fertilizer and vinasse (FxV). For the second ratoon, there were statistic high significant differences for the chemical fertilizer (F), for vinasse (V) and for the interaction between the chemical fertilizer and vinasse (FxV).

The average sugar yield per ha of the different treatments, are presented in table 2. In the treatments where no chemical fertilizers are added (F0V0, F0V1, F0V2, F0V3, F0V4), the sugar yield is increased in all the treatments where vinasse is applied as compared with no application. The application of 100 m^3 ha^{-1} (F0V4), increased sugar yield in 22 % for plant-cane, 30 % in first ratoon and 63 % in second ratoon in relationship with the treatment F0V0.

Variance analysis performed to these data showed that for sugar yield on plant-cane cycle, there were statistic high significant differences (1%) for vinasse application (V) and statistic significant differences (5%) for the interaction between the chemical fertilizer and vinasse (FxV). For the first ratoon, there were statistic high significant differences for the chemical fertilizer (F) and for vinasse (V) treatments. For the second ratoon, there were statistic high significant differences for the chemical fertilizer (F), for vinasse (V) and statistic significant differences for the interaction between the chemical fertilizer and vinasse (FxV).

Table 1. Average cane yield for the different chemical fertilizer and vinasse doses.

	Cane Yield (mg ha^{-1})		
Treatment	Plant-cane	First ratoon	Second ratoon
F0VO	94	77	51
FOV1	116	86	59
FOV2	112	96	75
FOV3	116	82	71
FOV4	119	95	84
F1V0	95	96	89
F1V1	105	100	110
F1V2	140	105	100
F1V3	124	106	99
F1V4	139	110	111
F2V0	93	80	69
F2V1	112	100	81
F2V2	136	103	72
F2V3	97	94	87
F2V4	94	109	100

Table 2. Average sugar yield for the different chemical fertilizer and vinasse doses.

	Sugar yield (mg ha^{-1})		
Treatment	Plant-cane	First ratoon	Second ratoon
F0VO	9,56	6,56	5,45
FOV1	12,79	7,68	6,41
FOV2	11,75	8,52	8,15
FOV3	12,95	7,83	7,75
FOV4	11,65	8,52	8,91
F1V0	11,22	9,09	9,75
F1V1	10,83	9,86	12,36
F1V2	15,61	10,17	10,03
F1V3	13,63	10,03	10,61
F1V4	14,69	10,72	12,71
F2V0	9,54	7,53	7,39
F2V1	12,43	9,79	9,06
F2V2	14,69	9,57	7,55
F2V3	9,87	9,36	10,11
F2V4	9,53	10,73	10,68

The data on table 1 and table 2 shows that yield of cane and sugar of the crop is always larger in plant-cane, and decreases with successive ratoons. This is the common trend of yield on sugar cane production (2, 3, 8, 10).

Results expressed as mean yields in cane per hectare for the different doses of vinasse applied over the three cultivation cycles are shown in table 3.

Table 3 shows that in the case of plant-cane and first ratoon, application of 50 m^3 ha^{-1} (V2) and 100 m^3 ha^{-1} (V4) of vinasse, significantively increased average cane yield. For second ratoon, all the vinasse doses used increased cane yield. In relative terms, the data shows that application of 50 $m^3.ha^{-1}$ of vinasse (table 3), increased cane yield by 38% as compared with the control sample (0 m^3 ha^{-1}). For first ratoon and second ratoon, the application of 100 m^3 ha^{-1} increased average cane yield by 24% and 38% respectively as compared with the control sample (F0V0).

These results show that the use of vinasse could be effectively used to increase the sugarcane yield. Similar results were reported by Rossetto (9), who obtained the best yield in cane per hectare when applied 60 m^3 ha^{-1} of vinasse on plant-cane growing cycle. COPERSUCAR (2), reported that application of vinasse to cane ratoons over three consecutive years, resulted in an increase in yield with a dose of 90 m^3 ha^{-1} as compared with no vinasse application.

Results expressed as mean yields in sugar per hectare for the different doses of vinasse applied over three consecutive production cycles are shown in table 4.

Application of 50 m^3 ha^{-1} of vinasse (V2) to plant-cane cycle, increased sugar yield (table 4), in yield of 39% conpored with control treatment (V0). For the first ratoon and for the second ratoon, the application of 100 $m^3.ha^{-1}$ of vinasse (V4), also increased average sugar yield (table 4), the increase being 30% and 43% respectively as compared with the control treatment (0 m^3 ha^{-1}). These results show that the application of vinasse as compared with the control sample, increased sugar yield.

Table 5 shows some advantages of using vinasse as a fertilizer. The table 5 shows that for plant-cane, the application of 80 kg ha^{-1} of N and 45 kg ha^{-1} of P_2O_5 supplemented by 50 m^3 ha^{-1} of vinasse (F2V2), increased yield in 41 mg ha^{-1} of cane and in 3,47 mg ha^{-1} of sugar as compared with F1V0. That is, using vinasse as complement fertilizer on plant-cane, resulted in a yield increase of 43% in cane and 31% in sugar as compared with mineral fertilization.

On first ratoon, use of 80 $kg.ha^{-1}$ of N and 45 kg ha^{-1} of P_2O_5 plus 100 m^3 ha^{-1} of vinasse (F2V4), increased yield in 13 mg ha^{-1} of cane and in 1,64 mg ha^{-1} of sugar as compared with mineral fertilization (F1V0). That is using vinasse as complement fertilizer resulted in a 13% increase in cane and 18% increase in sugar yield as compared with solo mineral fertilization (F1V0).

In second ratoon, the treatment F2V4, increased yield in 11 mg ha^{-1} of cane and in 0,93 mg ha^{-1} of sugar as compared with the treatment F1V0 (table 5). On second ratoon, using vinasse as complement fertilizer re-

Table 3. Sub plots (vinasse) effect on cane yields as compared by using a Duncan multiple range test*.

Treatment & Vinasse	Dose ($m^3.ha^{-1}$)	Cane Yield (mg ha^{-1}) Production cycles		
		Plant-cane **	First Ratoon *	Second Ratoon **
V0	0	93,67 b	84,17 b	69,33 c
V1	25	110,92 ab	95,58 ab	83,65 b
V2	50	129,33 a	101,42 a	82,37 b
V3	75	112,17 ab	94,00 ab	85,92 b
V4	100	117,33 a	104,75 a	95,69 a

* Statistic differences at 5% level.
** Statistic differences at 1% level.
Data with same letters in each column are not statistically different from each other.

sulted in a 12% in cane and 10% in sugar yields as compared with solo mineral fertilization (table 5).

These results demonstrated that by using vinasse as a complement fertilizer, sugarcane productivity increases as cane and sugar production per hectare is increased.

As the vinasse used in this experiment has a content of 2 kg m^{-3} of N, 2,3 kg m^{-3} of P_2O_5 and 7,5 kg m^{-3} of K_2O, the analysis of these data suggests that with the dose of 50 m^3 ha^{-1} of vinasse, 55% of the N, 72% of the P_2O_5 and 100% of the K_2O provided by the mineral fertilization could be replaced by the vinasse.

Comparing the mineral fertilizer dose usually applied in the river Turbio plain area (F1V0), with the use of vinasse, the data suggests that application of vinasse as complement fertilizer (F2V4), increases sugarcane productivity because both, the yield of

Table 4. Sub plots (vinasse) effect on sugar yield as compared by using a Duncan multiple range test.*

Treatment & Vinasse	Dose (m^3 ha^{-1})	Sugar Yield (mg ha^{-1}) Production cycles		
		Plant-cane **	First Ratoon **	Second Ratoon **
V0	0	10,11 b	7,73 b	7,53 c
V1	25	12,02 ab	9,11 ab	9,37 b
V2	50	14,01 a	9,42 a	8,91 b
V3	75	12,15 ab	9,07 ab	9,49 ab
V4	100	11,96 ab	10,07 a	10,77 a

** Statistic differences at 1% level.
Data with same letters in each column are not statistically different from each other.

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Table 5. Comparison of mineral fertilization (F1V0) usually applied for sugarcane in the area against application of 50 $m^3.ha^{-1}$ vinasse (F2V4) plus complementary mineral fertilization.

Treatment	Production			
	Cane mg ha^{-1}	Sugar mg ha^{-1}	Increase (%) Cane	Increase (%) Sugar
Plant				
F1 VO: 180 kg ha^{-1} N+160 kg ha^{-1} P_20_5+220 kg ha^{-1} K_20	95	11,22		
F2 V2: 80 kg ha^{-1} N+45 kg ha^{-1} P_20_5+50 m^3 ha^{-1}Vinasse	136	14,69	43	31
Ratoon I				
F1 VO: 180 kg ha^{-1} N+160 kg ha^{-1} P205+ 50 kg ha^{-1} K_20	96	9,09		
F2 V4: 80 kg ha^{-1} N+45 kg/ha P_20_5+100 m^3 ha^{-1} Vinasse	109	10,73	13	18
Ratoon II				
F1 VO: 180 kg ha^{-1} N+160 kg ha^{-1} P_20_5 + 50 kg ha^{-1} K_20	89	9,75		
F2 V4:80 kg ha^{-1} N+45 kg ha^{-1} P_20_5+100 m^3 ha^{-1} Vinasse	100	10,68	12	10

the crop and the yield in sugar per hectare were significantly increased (table 5).

The application of vinasse to the soils for sugarcane fertilization reduces its disposition in waterways and so its contaminant effects besides increasing sugarcane yields and reducing fertilizer expenses.

Conclusions

Vinasse increased sugarcane productivity because the yield of the crop and the yield in sugar per hectare were both significantly increased.

Highest yields were obtained when 50 m^3 ha^{-1} of vinasse were incorporated for plant-cane cycle and 100 m^3 ha^{-1} of vinasse for first and second ratoons.

With the use of vinasse as a fertilizer, acceptable sugarcane yields were obtained without the addition of mineral fertilizer. However, it was found that mineral fertilizer plus vinasse as a complement was necessary to reach higher production levels.

The application of 50 m^3 ha^{-1} vinasse would substitute for 55% of the N, 72% of the P_2O_5 and 100% of the K_2O that has to be applied using mineral fertilization.

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