USE OF VINASSE DILUTIONS IN WATER AS AN ALTERNATIVE FOR IMPROVING CHEMICAL PROPERTIES OF SUGAR CANE-PLANTED VERTISOLS

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ABSTRACT. For five years, a stationary field experiment was carried out at "Enrique Varona" Agroindustrial Complex, with the objective of evaluating the cumulative and residual effect of applying different vinasse dilutions in water at the rates of 1/2.5, 1/5, 1/10 and 1/20 on Vertisol chemical properties and sugar cane yields. It was observed that vinasse dilutions increased the content of calcium and other cations, as well as base exchange capacity. Results proved that treatments using vinasse with water improved soil intercationic balance; also, base-exhange capacity and yields increased and the useful life period of the strain lengthened.

Key words: vinasse, residues, distilling, vertisols, wastewater

RESUMEN. Se realizó un experimento de campo estacionario en áreas de producción del Complejo Agroindustrial "Enrique Varona", con el objetivo de evaluar el efecto acumulativo y residual de aplicaciones de vinaza diluida con agua en las variantes vinaza-agua 1/2.5, 1/5, 1/10, 1/20 en algunas propiedades químicas de Vertisoles y los rendimientos de la caña de azúcar durante cinco años. Los resultados demuestran que en las variantes donde se aplicó la vinaza diluida con agua, se mejoró el balance intercationico del suelo, se incrementó además, la capacidad de cambio de bases, los rendimientos y se alargó el período de vida útil de la cepa.

Palabras clave: vinaza, residuos, destilación, vertisoles, aguas residuales

INTRODUCTION

Within the strategy of science, technology and environment up to the year 2005, at "Enrique Varona" Agroindustrial Complex, located in Ciego de Avila, there is the task of minimizing environmental impacts caused by the distillery and sugar factory, which are the main pollutants in this sense, in order to increase efficiency in production and economy. For this purpose, several methods are used, such as adding water to liquid residuals for their further use on sugar cane fertigation, due to the lack of oxidation ponds, benefiting an area of around 938 hectares from January to April. However, there is not a scientifically founded methodology that allows defining dose, appropriate dilutions, as well as application methods together with their effects on the soil and short, medium and long-term crop development,even though there is a national methodology for fertirigation (1). The present work was carried out with the objective of evaluating the effect of different vinasse dilutions with water on some chemical properties of a Vertisol planted with sugar cane, as well as their cumulative and residual effect on the soil and sugar cane yields.

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MATERIALS AND METHODS

The study was carried out at the production areas of "Enrique Varona" Agroindustrial Complex (Block 128), during the period between February, 1995 and March, 2000, using a nongleyed dark plastic soil. A randomized block design was used with four replications and five treatments, by means of which vinasse was diluted in water at the rates of 1/2.5, 1/5, 1/10 and 1/20; in addition to a control treatment, submitted to irrigation using ground water (twice per cycle) and NPK mineral fertilization at a dose of 60.2 kg $N.ha^{-1}$. Ammonium nitrate (NH_4NO_3) was used as carrier, as well as 25 kg P_2O_5 as triple superphosphate and 80 kg $K_2O.ha^{-1}$ as potassium chloride.

Vinasse dilutions were applied during plant cane and first ratoon stages following a partial net pattern of 300 $m^3.ha^{-1}$ and two irrigations per cycle. The remaining irrigations were performed using ground water, according to crop water needs.

The cumulative effect was evaluated at first ratoon, whereas the residual effect at the fifth harvest. Organic matter, pH and exchangeable cations (calcium, magnesium, potassium and sodium) were evaluated, as well as base exchange capacity, according to Cuban patterns (2, 3, 4). The influence of dilutions on sugar cane agricultural yields was also evaluated.

Vinasse dilutions were applied by means of a cart tank with estimated volumes for warranting the appropriate dose, following furrow irrigation technique.

Under field conditions, research works were conducted according to the methodology established by the

Department of Soil and Agrochemistry from INICA (5), with the following particularities: plots of 32 m^2 at a distance of 2 m between plots and 4 m between replications were used. Sugar cane was planted in each plot consisting of four furrows of 5 m long, separated 1.60 m (such plot dimensions are regarded as net harvest area). Three-eyed propagules, at a density of 12 buds per meter were used, as well as C-266-70 variety, according to what is recommended (6).

Soil samplings, collected in five cores of each plot after crop cycle, were extracted from a depth between 0.00 and 0.20 m, using an agrochemical bore for obtaining compound samplings. Agricultural yield was also determined, from the total weight of calluses within the whole plot.

After the chemical characterization, of the residue of alcohol production (vinasse), from "Nauyú" distillery, high concentrations of organic matter, calcium, magnesium and potassium are presented, giving an inestimable value as fertilizer. The residue is also characterized by a strong acidity (Table I).

Table I. Chemical characterization of vinasse from "Nauyú" distillery, located in Ciego de Ávila

Determination	UM	n	$\bar{x}$	VC (%)
pH	-	12	4.61	0.57
EC	$mS.cm^{-1}$	10	9.90	15.95
OM	$g.L^{-1}$	8	31.60	26.30
C	%	13	5.61	16.34
Na^+	$mg.L^{-1}$	13	304.18	23.51
K^+	$g.L^{-1}$	14	7.85	22.49
Ca^{2+}	$g.L^{-1}$	9	3.32	15.84
Mg^{2+}	$g.L^{-1}$	10	2.05	26.57
Cl^-	$g.L^{-1}$	10	3.79	16.43
$CO_3^{=2}$	$g.L^{-1}$	11	0	0
HCO^-_3	$g.L^{-1}$	11	7.20	33.12
N	$g.L^{-1}$	4	0.88	10.62
P_2O_5	$g.L^{-1}$	7	19.87	25.00
TSS	$g.L^{-1}$	10	6.33	8.25

n- Sampling times
x- Mean value from the analysis results
VC- Variation coefficient
EC- Electric conductivity ($mS.cm^{-1}$)
OM- Organic matter ($g.L^{-1}$)
C. Total carbon (%)
TSS. Total soluble salts ($g.L^{-1}$).

The two-way classification variance analysis applied, through which treatments or replications were considered factors or causes of variation, allowed using Duncan's Multiple Range Test, in cases where significant differences among means were found, using SPSS statistical package, version 8.0, supported on Windows operating system.

RESULTS AND DISCUSSION

Influence of vinasse dilutions on soil chemical and physical characteristics evaluated

Organic matter. Organic matter plays an important role for improving soil physical status, increasing water infiltration speed, reducing soil density and favoring formation of the agronomically most valuable aggregates (7).

Table II shows changes in contents of organic matter, after applying vinasse dilutions during plant cane and first ratoon stages, as well as the residual effect during the fifth harvest.

Effective increases in organic matter are achieved by applying vinasse dilutions, where 1/5 and 1/10 variants show significant differences during the first year, in relation to the remaining treatments. Values with equal behavior for such variants are found during the cumulative effect. Certain decrease of the residual effect content is found in the fifth harvest, which is caused by the interruption of applications for three years. However, the reported contents for the treated variants differ in relation to the control.

In this sense, distillery residue is an appropriate source of soil organic matter, due to the high contents it presents. At the same time, it constitutes an excellent way of restoring soil damages and contributes to counteract the main causes of poor yield (8). It has been proved that continuos sugar cane cropping provokes important changes in vertisol chemical features, which are mainly expressed through reduction of organic matter content (9). Better humification and cationic balance are obtained, in general, when a more balanced vinasse dose (1/5) is applied, such variant being the best alternative for performing vinasse applications in the fields.

Similar results have been reported, after applying increasing vinasse doses to different types of soils (10), were organic matter prevailed in time, to a certain extent, even though it increased due to the direct effect produced.

pH behavior. During three years of evaluation, no variant of diluted vinasse affected soil acidity, values ranging near neutrality. This approves the use of such waters for sugar cane fertigation, since there is no influence of residual chemical composition on soil acidity, mainly due to the high buffering capacity of most vertisols. The pH values reported are considered appropriate for sugar cane plantation (11), which develop fully without affecting pH values (between 6 and 8). Significant changes in soil acidity were not found (12, 13) after applying distillery residues, issue that serves as an explanation for the results up to now. However, this parameter should be carefully controlled due to its importance and its influence on vegetable nutrition. The stability of such parameter while the experiments were conducted allows using vinasse in this alternative.

Exchangeable cations. The behavior of cations from the exchange complex, as well as their dynamics, where diluted vinasse was used, is an important soil physical and chemical feature. Contents of exchangeable calcium increased in all variants, with regard to the control, and were more intense during the second year. Variants 2D and 3D presented the best behavior, showing increases from 38.00 $cmol(+).kg^{-1}$ to 42.00 and 40.10 $cmol(+).kg^{1}$ in the control, respectively, and reaching values of 53.28 and 49.81 $cmol(+).kg^{-1}$ during the second year (cumulative effect). Such contribution is owing to the high base content of residuals.

Table II. Chemical and physico-chemical features evaluated at a depth of 0.00-0.20

Year	Var.	OM (%)	PH	Ca^{2+}	Mg^{2+}	K^+	Na^+	BEC	Yield ($t.ha^{-1}$)
1º	OD	3.16 c	7.60	38.00 c	15.01 a	1.10 c	1.00 b	55.11 b	89.23 e
	1D	3.18 c	7.53	39.61 b	13.92 a	1.13 c	0.94 ab	55.74 b	108.9 d
	2D	3.73 a	7.42	42.00 a	13.33 a	1.57 a	0.90 c	57.80 a	146.7 a
	3D	3.66 a	7.62	40.10 b	10.42 b	1.50 ab	0.95 a	52.97 c	130.6 b
	4D	3.47 b	7.65	38.20 c	9.16 b	1.48 b	0.98 a	49.82 d	118.4 c
	DE $\bar{x}$	0.076	0.503	0.597	0.496	0.042	0.034	1.074	4.493
2º	0D	3.18 c	7.60	39.21 d	14.92 a	0.98 e	1.08 a	56.19 d	86.14 e
	1D	3.25 c	7.50	43.58 c	12.56 b	1.26 d	0.92 d	58.50 c	110.9 d
	2D	3.84 a	7.52	53.28 a	11.40 bc	1.75 a	0.99 c	67.42 a	156.3 a
	3D	3.78 a	7.64	49.81 b	11.96 bc	1.63 b	1.01 b	64.52 b	148.7 b
	4D	3.52 b	7.60	44.25 c	10.20 c	1.50 c	1.06 ab	57.10 cd	131.5 c
	SE $\bar{x}$	0.087	0.024	0.686	0.47.8	0.051	0.032	1.142	5.902
5º	0D	3.22 c	7.65	39.14 c	14.99 a	0.95 d	0.99 a	56.07 bc	50.25 e
	1D	3.26 c	7.51	40.16 c	12.99 b	1.19 c	0.90 b	55.24 c	54.96 d
	2D	3.70 a	7.41	44.91 a	12.80 b	1.60 a	0.84 d	60.15 a	76.09 a
	3D	3.65 ab	7.70	42.74 b	12.10 b	1.55 a	0.86 cd	57.25 b	69.40 b
	4D	3.50 b	7.61	39.91 c	10.01 c	1.42 b	0.89 bc	52.23 d	59.76 c
	SE $\bar{x}$	0.080	0.856	0.455	0.506	0.035	0.028	1.061	2.230

Var: vinasse- water dilution. OD control; 1D(1/25); 2D(1/5); 3D(1/10); 4D(1/20)
OM: Soil organic matter content (%)
Ca^{2+}: Calcium; Mg^{2+} magnesium; K^+ potassium; Na^+ sodium, exchangeable cations, (cmol(+).kg^{-1})
BEC. Soil base exchange capacity. (cmol(+).kg^{-1})
Yield. Agricultural yield ($t.ha^{-1}$)
SE*x*. Mean standard error
(a, b, c...): Means with index letters indicate differences according to Duncan ($p<0.05$)
Variance analyses were performed per each property every year

The lowest increase was obtained by using 1/20 (4D) dilution in the first year, where the mixture is less concentrated.

Increases achieved by vinasse dilutions denotes its marked effect as calcium source for these soils, since their contents increase at plant cane stage and prevails not only at first ratoon, but also during the residual effect in the fifth harvest.

Magnesium contents decreased for all variants in which residues were applied, with regard to the control; this was more evident as vinasse was more diluted in water. Therefore, this alternative for using vinasse is not considered a source for adding this nutrient to the soil; it should be always seen as an indicator for determining a period of time, during which a residue with high contents of potassium could be applied to the soil. These results are in correspondence with those previously obtained (14), regarding the fact that the effects of sugar industry residuals on the soil are mainly produced on its exchangeable bases, since high contents of exchangeable potassium tend to reduce those of magnesium, due to the marked antagonism between both nutrients.

On the other hand, exchangeable potassium (K^+) increased significantly during the first two years. In this sense, variants 2D and 3D stood out during the first year, presenting increases from 1.10 cmol(+).kg^{-1} to 1.57 and 1.50 cmol(+).kg^{-1} in the control, respectively, also reaching values of 1.57 and 1.63 cmol(+).kg^{-1} during the cumulative effect. Interrupting applications during three years brought about reductions in all variants in relation to the previous years, even though values were even superior to the control, showing the lasting influence of the residual effect.

One feature of such residue, which serves as an explanation to its behavior, is that of containing high levels of potassium. Increments produced by vinasse prove, through its use, an appropriate crop nutrition, which is one of the most important issues to be taken into account when analyzing residues with such features (15).

According to some researchers, the main restriction for using residues as fertigation is their high contents of salt. However, there is poor reference to potassium influence on sodium (Na^+) that, in most cases, prevents salts in the residue from damaging crops.

Diluted vinasse applications reduce exchangeable sodium contents; such effect lasts up to the fifth harvest. Therefore, it could be affirmed that such residues constitute an appropriate way for counteracting soil exchangeable sodium levels, it being an effective alternative for improving this important parameter.

Base exchange capacity (BEC or S value). Increments of exchangeable cations provoked a higher base exchange capacity, as it is described in Table II, where variant 2D stood out showing increases in most of the previously analyzed nutrients. Exchange capacity increased for such variant, reaching values of 57.80 and 67.42 cmol(+).kg^{-1} during the first and second year, respectively, compared to the control (55.cmol(+).kg^{-1}). For the fifth year, this value dropped to 60.15 cmol(+).kg^{-1}, due to changes presented by each of the analyzed bases as a consequence of interrupting fertigation during this period, showing soil tendency to recover its initial chemical conditions.

Influence of vinasse dilutions on sugar cane yield. By using vinasse dilutions, yield and its components increased noticeably at plant cane and first ratoon stages.

In the first harvest, yield values of up to 146 t.ha^{-1} were obtained for variant 1/5, compared to the control (89.23 t.ha^{-1}). In first ratoon, values of 156 t.ha^{-1} were obtained for the same variant, which is in correspondence with the cumulative effect produced.

Concerning the residual effect, yield is still high in the fifth harvest, which is more noticeable for variant 1/5. However, these increases are poorer than those obtained in the previous harvests, since there is no nutrient supply during this period.

Results showed that distillery residues in the alternatives used warrant high yields with residual effect on the crop. They also constitute an appropriate water and nutrient source for satisfying sugar cane nutritional needs.

CONCLUSIONS

Applying vinasse diluted in water increased the levels of organic matter, calcium and potassium in the exchange complex and also improved base exchange capacity. Soil acidity was not affected, this indicator showing stability during the evaluated years. Marked cumulative and residual effects were achieved in the second and fifth years, respectively, agricultural yield being favored. Using vinasse diluted in water is an effective and economic alternative for sugar cane irrigation and fertilization (mainly in variants 1/25 and 1/5), avoiding the strong environmental pollution caused by residues in the north part of Ciego de Ávila.

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