Effects of Sugarcane-byproduct, Vinasse on Chemical Properties of Soil and Initial Growth of Sugarcane Varieties SL 83 06 and SL 96 128

B.R. Kulasekara[1]*, A.S. Ranagalage[2] and H.A.S. Weerasinghe[1]

[1] *Sugarcane Research Institute, Uda Walawe, Sri Lanka*
[2] *Faculty of Agriculture, University of Peradeniya, Sri Lanka.*

Corresponding author: kulasekaraya@gmail.com

ABSTRACT

Vinasse is an aqueous effluent of the distillation unit in the sugar-alcohol industry and a problem to the sector due to its potential effects as an environmental pollutant. However, proper usage of vinasse contributes to improving soil quality and agricultural productivity. The objectives of this study were to evaluate the effects of sugarcane vinasse on soil chemical properties and initial growth attributes of the sugarcane plant. The research consisted of a laboratory and a pot experiment. In the laboratory experiment, concentrated vinasse (volume 1:10) was applied to soil at the level of 40 m^3/ha, and non-concentrated vinasse was applied to soil in four levels; *viz.* 40, 60, 80, and 120 m3/ha to evaluate soil chemical properties (pH, electrical conductivity, organic matter, nitrogen. phosphorus, and potassium). Data were collected up to for 98 days in the laboratory experiment. Similar treatments were applied for soil pot culture-grown varieties, SL 83 06 and SL 96 128 as the above ratios of concentrated and non-concentrated vinasse under net house condition. The results of the laboratory experiment indicated that the concentrated vinasse-treated soil samples showed considerably higher values for all tested chemical properties except soil pH. Both varieties had performed well in 40 m^3/ha non-concentrated vinasse level. However, the variety, SL 83 06 showed higher performance than SL 96 128 in shoot dry weight, root length, shoot dry weight, and root dry weight at 40 m^3/ha non-concentrated vinasse level. Since, findings indicated that, lower doses of non-concentrated vinasse are more favorable to plant growth with a stimulatory effect on plant initial growth.

Keywords: Concentrated and non-concentrated vinasse, soil chemical properties, Sugarcane

INTRODUCTION

Recently, the high cost of fertilizers and concerns about environmental protection have been great incentives to study the recycling of the large quantities of organic residues produced as byproducts of the sugar and alcohol agro-industries in agriculture. Vinasse is an aqueous effluent of the distillation process in the sugar-alcohol industry. Disposal of vinasse has become an acute problem for the sector due to the large quantities produced and its potential effects as an environmental pollutant. The composition of vinasse varies, but in general, it is composed mainly of water, organic matter, and mineral elements and characterized by undesirable colour, foul odour high biological oxygen demand (BOD) chemical oxygen demand (COD). It contains many useful elements and can be used as a dilute organic liquid fertilizer to improve soil properties and increase crop yield while alleviating environmental pollution (Pande *et al*., 1995).

The quantity of vinasse produced depends on the processing technique employed and varies between 10 and 18 litres of vinasse per litre of alcohol produced. (Silva *et al.*, 2007). The disposal of this residue represents a major environmental concern, mainly due to the vast amount of wastewater (about 97%) and high organic loads. The environmental damage caused by discarding vinasse into the soil or running water was an incentive for studies aiming to find alternative, economic applications for this residue. Thus, its application in the soil is one of the most cost-effective and efficient ways of utilization, leading to improvement in the physical and chemical characteristics of soil and increasing crop yield. (Canellas *et al.,* 2003; Tang *et al.*, 2006). Results from such studies indicate that properly used vinasse contributes to improvements in soil quality (Ou *et al.*, 2002) and agricultural productivity (Li *et al.*, 2007 and Shang *et al.*, 2013). There have been some records about the effects on soil properties including physical, chemical, and microbial aspects (Singh *et al.*, 2008). However, more evidence is needed to illustrate and authenticate the mechanisms of vinasse application on the promotion of plant growth.

Organic matter, K, N, Ca, and Mg are the main chemical components of vinasse, K being the most important mineral element for the agricultural use of the residue. It is possible to estimate the potential contribution of vinasse for the annual recycling of nitrogen, phosphorus, and potassium in cultivated land with sugarcane. Gomez (1996) stated that, in three years of field trials, the application of vinasse increased sugarcane yield significantly without reducing quality further he also suggested that vinasse could substitute for 55% N, 72% P, and 100% of K required to sugarcane in Venezuela. Further, vinasse is used by sugar mills in Brazil as a fertilizer. It can replace, in part or full, potassium fertilizers for sugarcane (Su *et al*., 2009), representing an economical alternative. So effective usage of vinasse provides the best option for reducing the cost of production and increasing profit in sugar industries.

Nevertheless, for sugar mills with limitations to dispose of vinasse in the soil, one solution would be to transport it to distant locations. Nevertheless, this would result in a cost increase due to a large amount of water waste. Under such a scenario, as an economical alternative for transportation, the volume of vinnase has been reduced by evaporation to obtain the byproduct with lower water content. The non-concentrated and concentrated vinasse have different compositions, water content, and mineralization pathways (Parnaudeau *et al.*, 2006). The concentrated vinasse by evaporation is increasingly used by sugarcane mills in Brazil. However, the amount of vinasse applied in agriculture must follow appropriate guidelines, which vary according to the soil characteristics. In Sri Lankan scenarios, there is an already established recommendation on direct soil application of vinnase to sugarcane fields. However, it is required to monitor and study furthermore on this matter further for upcoming problems related to vinasse in sugarcane-growing soils. A specific recommendation must be followed for each condition to prevent excessive use and consequent mineral lixiviation. Therefore, this study aimed to evaluate the effects of sugarcane vinasse (non-concentrated and concentrated) on soil-chemical properties and initial growth attributes of sugarcane varieties SL 83 06 and SL 96 128

MATERIALS AND METHODS

Initial Sample Collection

Soil samples were collected from the research farm of the Sugarcane Research Institute in 2015. Soil is Reddish Brown Earth and it had the following chemical characteristics; pH: 6.6, EC: 2.6 ms/cm, N: 800 ppm, P: 29 ppm, K: 190 ppm, and OM: 7.5 %.

The non-concentrated vinasse (NCV) used in the experiment was obtained from the sugar mill distillery, Sevenagala with a high content of water. The concentrated vinasse (CV) was obtained by the evaporation process of the NCV, concentrated ten times its volume. The chemical composition of NCV and CV are shown in Table 1.

Laboratory experiment

In the laboratory experiment, the treatments consisted of one dose of CV (40 m^3/ha) and four levels of NCV (40 m^3/ha, 60 m^3/ha, 80 m^3/ha, 120 m3/ha) including a control (without vinasse application). The above-mentioned levels of vinasse were incorporated in plastic bottles with 100 g of soil collected from the research farm and kept at room temperature. Soil moisture content was maintained at 70% field capacity in all the treatments by adding distilled water. Since CV was highly viscous, it was diluted with the same amount of distilled water used to increase moisture to field capacity. The samples were analyzed 7, 14, 28, 42, 70, and 98 days after treatment allocation to evaluate soil chemical properties (pH, electrical conductivity, organic matter, nitrogen. phosphorus, and potassium).

Pot experiment

Single bud setts of sugarcane (*Saccharum spp.hybrid*) varieties SL 83 06 and SL 96 128 were grown in pot culture conditions containing soils collected from the research farm (pH 6-7) with laboratory-tested levels of NCV and CV with control (Water treatment). The pots were kept in net house condition, and growth attributes (shoot length, root length, shoot dry weight, root dry weight) were recorded for 30 days after planting.

Data analysis

In both experiments, Standard deviation (+SD) was calculated using means of three replicates as described by Panse and Sukhatme (1985). As per the collected growth attributes data shoot length index, root length index, shoot dry weight index, and root dry weight index were calculated as follows.

$$\text{Index Value} = \frac{\text{Value of the growth attribute}}{\text{Value of the growth attribute of control treatment}} \times 100\%$$

RESULTS AND DISCUSSION

Chemical composition of non-concentrated and concentrated vinasse

Chemical composition of vinasse varies considerably from one distillery to another depending on the raw material used in fermentation, the type and efficiency of fermentation, distillation, and the varieties and the degree of ripeness of the cane used. (Mary et al., 1996). NCV and CV used for the study were analyzed for some chemical parameters (Table 1).

Table 1: Chemical composition of non-concentrated and concentrated vinasse

waste	pH	EC mS/cm	Organic carbon	Nitrogen (mg/L)	Phosphorous (mg /L)	Potassium% (mg /L)
NCV	4.5	39.7	3%	1204	320	6000
CV	5.3	78.4	9%	2789	624	44000

Effects of sugarcane vinasse on chemical properties of soil

Figure 1-5 presents variations of pH, EC, OM, N, P, and K in soil treated with different levels of NCV and CV with the time in laboratory conditions. The results of the laboratory experiment indicated that the CV-treated soil samples showed higher values for all tested chemical properties except soil pH.

Concerning the pH, it was observed that the application of NCV with increasing rates to the investigated soil had a slight effect on soil pH. Conversely, when CV is applied soil becomes more acidic than NCV applied to the soil. pH values of NCV-applied soil range from 7.2-7.6 (Figure 1). Even though NCV is an acid residue with pH 4-4.5, the soil buffers its pH value within a range of neutral which is favorable for plant growth.The effect of CV on pH may be explained by the production of organic acids and hydrogen ions (H+). The decomposition process accelerates the release of CO_2 and organic acids that would reduce soil pH. This finding confirms those obtained by EI-Leboudi *et al.,* (1988) and Arafat (1994). The optimum soil pH for sugarcane growth is about 5.5 - 6.5 level and vinnase application has not adversely affected the optimum soil pH. Data also show that the Electrical conductivity (EC) values of the CV and NCV treated soil increased with the increasing rates of vinasse application, but no adverse effect on sugarcane plant growth. pH and EC levels did not show any large variation with the time.

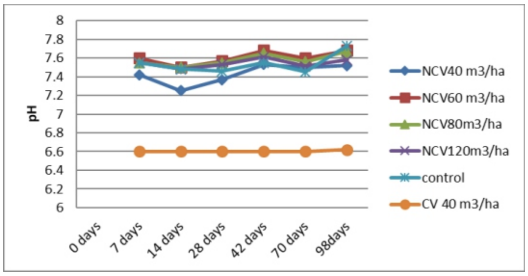

Figure 1: Variation of soil pH values in different levels of NCV and CV with the time in laboratory .

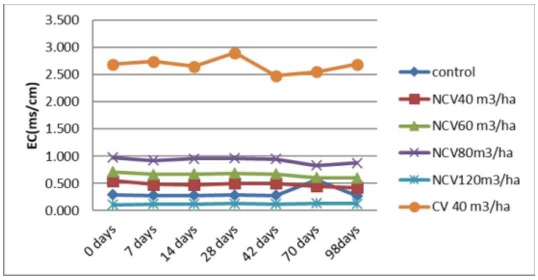

Figure 2: Variation of soil EC values in different levels of NCV and CV with the time in laboratory conditions.

Also, vinnase application increased the soil N, P, K, and organic matter levels with increasing rates of vinasse applied. The highest N, P, and K levels were observed in CV 40 m3/ha applied to the soil, and the highest OM content was in NCV 120 m3/ha level. According to Rossetto *et al.*, (2008) stated that in general vinasse presents a high content of organic matter and potassium. Thus its application in the soil is one of the most cost-effective and efficient ways of utilization of sugar alcohol industry effluent.

The most striking change was the tremendous increase in soil OM, N, and K content, as the result of treating the soil with CV. The percentage increase in the organic matter was more than 50% at the rate of CV 40 m^3/ha relative to the control (Figure 3). Similar results were obtained by Orlando Fillo (1996), who stated that the addition of vinasse to soil led to an increase in the amount of organic matter and K content.

It was observed from Figures 4, 5, and 6 that the extractable concentration of N, P, and K in soil treated with CV increased relative to NCV. The rate of increase depends mainly on the rate of vinasse applied. The magnitude variation of residual extractable potassium was observed with respect to the rate of vinasse applied. The highest values of N, P, and K were observed in CV-treated soils. Phosphorus and potassium contents gradually increased with time except for nitrogen. Conversely, the N level in NCV-treated soil has decreased with time. However, the N level in CV-treated soil has gradually increased at a slow rate and time. The above results further authenticate the findings of Alinne *et al.,* (2013), as they stated that the NCV is a good alternative to be applied as a soil nutrient source. However, higher doses promote N losses by denitrification due to high water content.

N mineralization and availability of nitrogen highly depend on the water content, aeration, quantity, and nature of organic matter added to the soil by CV and NCV and their doses, which produced distinct effects on the indigenous N, once the N addition affects the nitrogen transformation in the soil (Kuzyakov *et al*., 2000).

According to Alinne *et al.,* 2013 he stated the NCV is a good alternative to be applied for sugarcane crops but promotes N losses by denitrification due to high water content and it is also leaching losses.

The highest P and K levels observed in the CV 40m^3/ha ratio which is gradually increased with time. As with the vinnase application, P content was increased from 81 to 118 ppm and K content was increased from 800 to about 1200 ppm. These results indicate that the P and K levels in the soil were positively affected by the rate of vinasse applied to the soil (Figures 5 and 6). These results are in good agreement with those obtained by Gomez (1996) and Orlando (1996) and they stated that the application of vinasse could provide added nutrients to sugarcane, similar to mineral fertilizers application, besides the benefits of organic matter and micronutrients addition to the soil.

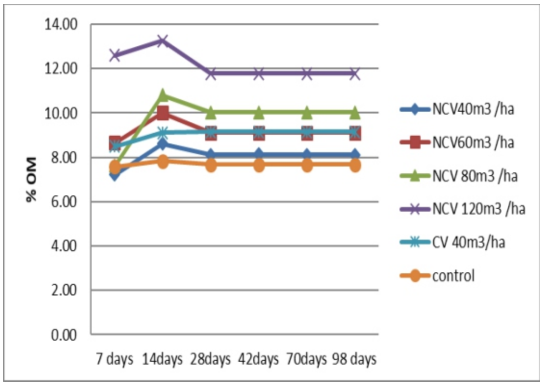

Figure 3: Variation of OM values with different levels of NCV and CV with the time in laboratory condition

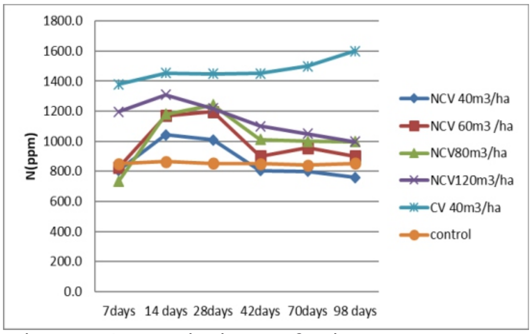

Figure 4: Variation of nitrogen content values in different levels of NCV and CV with the time in laboratory condition

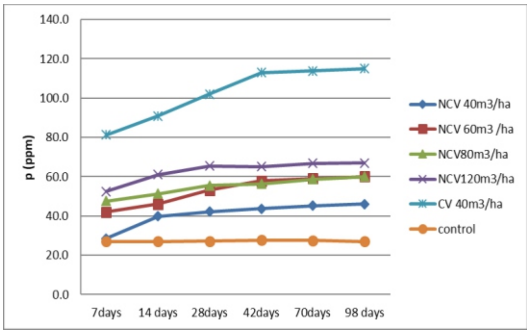

Figure 5: Variation of phosphorus content values in different levels of NCV and CV with the time in laboratory condition

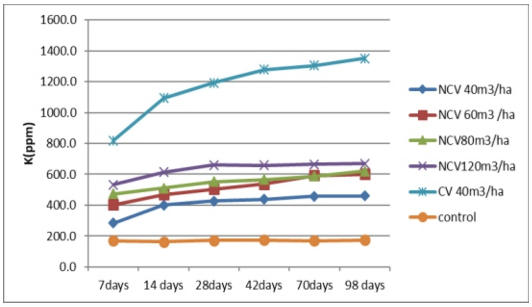

Figure 6: Variation of potassium content values in different levels of NCV and CV with the time in laboratory condition

Effects of sugarcane vinasse on initial growth of sugarcane varieties SL 83 06 and SL 96 128

Figures 7 and 8 present the effect of different levels of vinasse on improvement in shoot length (SL), root length (RL), root dry weight (RDW), shoot dry weight (SDW) of sugarcane variety SL 8306 and SL 96 128. Calculated index values of each growth attribute were compared and results revealed that very low rates of application of NCV (40 m^3/ha) showed better improvement in measured parameters for both varieties. However, variety SL 83 06 showed better performances than SL 96 128 for almost all tested growth attributes.

The variety SL 83 06 showed more or less similar performance as SL 96 128. The Highest improvement of Growth attributes was found in the 40 m^3/ha NCV level, closely followed by the 60 m^3/ha NCV level. SL 83 06 showed improvement in 80% in SDW, 90% in RL, 58 % in SDW, and 74 % in RDW in 40m^3/ha NCV level.

The variety SL 96 128 also showed the best performance in 40 m^3/ha NCV level, followed by 60 m^3/ha for measured growth parameters which was 80% improvement in SDW 38% in SL, 92 % in RDW, and 32 % in RL. Overall, plant performance decreased with the increasing rate of vinasse application in the pot experiment.

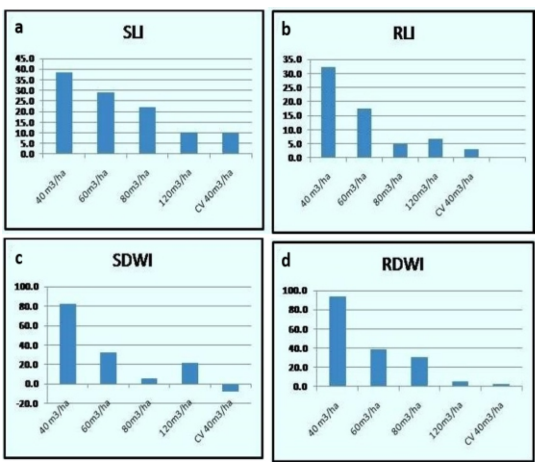

Figure 7: Effect of vinasse on bud sprouting (a), shoot length (b) root length (c), shoot dry weight (d), root dry weight of sugarcane variety SL 83 06

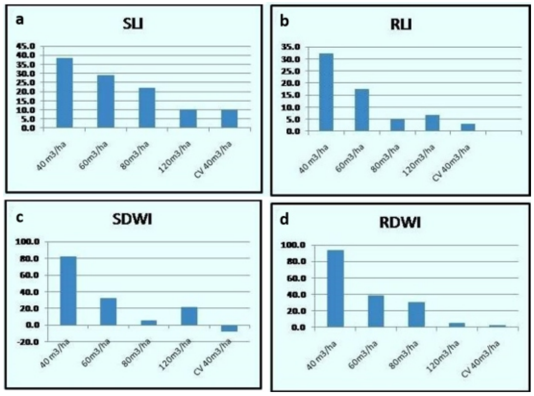

Figure 8: Effect of vinasse on bud sprouting (a), shoot length (b) root length (c), shoot dry weight (d), root dry weight of sugarcane variety SL 96 128

CONCLUSION

According to the results of the experiment, it could be concluded that the direct soil application of vinasse is a feasible method for its disposal. Also, it had a direct effect as a good source of elements and an indirect effect consisting of improvement of initial growth attributes of SL 96128 and SL 8306. Finally, results revealed that the lower doses of non-concentrated vinasse are more favorable to plant growth with a stimulatory effect on plant initial growth.

ACKNOWLEDGMENT

We wish to express our deepest gratitude to the former Directors of Sugarcane Research Institute, Dr. A P Keerthipala, and Dr. A Wijesuriya for granting to carry out this study. Furthermore, we extend our deepest appreciation to all the research and technical staff of the division of Crop Nutrition.

REFERENCES

Alinneda, S., Raffaella, A., Juliana, R.b., Piemonte, M., Takashi, M. 2013. Net and potential nitrogen mineralization in soil with sugarcane, Sugar Tech, society for Sugar Research & Promotion. 2013 159-164

Arafat, S.M. 1994. Evaluation of sugarcane filter mud on improving soil characteristics and watermelon Yield. Egypt J.Appl. Sci. 9(9):287-295

Canellas, L.P., Velloso, A.C.X., Runjanek, V.M., Guridi, F., Olivares, F.L., Santos, G.A. and Braz-filho, R. 2003. Distribution of the humified fractions and characteristics of the humic acids of a Ultisol under cultivation of eucalyptus and sugar cane. Terra Latinoamericana, 20:371-381.

Chandraju, S and Basavaraju, H.C. 2007. Impact of distillery spent wash on seed germination and growth of leaves vegetables: an investigation. Sugar J (SISSTA); 38:20–50.

El-Leboudi, A., Ibrahim, S.and Abdel–Moez, M. 1988. A trial for getting benefit from organic wastes of the food industry: I. effect on soil properties. Egypt J. Soil Sci.28:289-396.

Gomez, J.M. 1996. Effect of vinasse application on yield and quality of sugarcane (Abs.). Cana–de–Azucar. 14(1):15-34

Kuzyakov, Y., Freidel, J.K and Stahr, K.2000. Review of mechanisms and quantification of priming effects.soil biology and biochemistry. 32: 34-36

Li, Y.R., Zhu., Q.Z., Wang, W.Z and Solomon., S. 2007. Pre-emergence application of vinasse on sugarcane growth and sugar productivity in China. Sugar Tech.; 9:160–165

Mary, B., Recous, S., Darwis, D and Robin, D. 1996. Interaction between decomposition of plant residue s and nitrogen cycling in soil. Plant and soil science 181; 71-82

Nallathambhi, P., Viswanathan, R., Padmanaban, P., Moharaj, D and Jothi, R., (1999) Indian Sugar.;49:111–123.

Orland, Filho. J. 1996. Vinasse and fluid fertilizers on sugarcane in Brazil. Sugar Journal .; 8:120–125

Ou, S.B., Yang, H., Liang, H.Q. Zhou, H.Z, and Fang, Z.M. 2002. Review and prospect of vinasse management technology of China. Guangxi Journal of Light Industry 4: 10–21

Pandey, Dand Soni, P. 1994. Distillery effluent—a potential resource for irrigating forest seedbeds. Ambio.; 23:267–268.

Pandey, Dand Soni, P. 1995. Distillery effluent-a potential resource for irrigating forest seedbeds. Ambio.;23: 267–268.

Panse, V.G., Sukhatme, P. 1985. Statistical methods for agricultural workers. New Delhi: ICAR.

Parnaudeau, V., Nicolardot, B., Robert, P., Alavoine, G., Pages, J., Duchiron, F. 2006. Organic matter characteristics of food processing industry wastewaters affecting their C and N mineralization in a soil incubation, Bioresource. Technol. 97:1284–1295.

Ramana, S., Biswas, A.K., Kundu, S., Saha, J.K and Yadava, B.R. 2001. Effect of distillery effluent on seed germination in some vegetable crops. Bioresour Technol.;82:273–275. DOI: 10.1016/S0960-8524(01)00184-5.

Rani, R and Srivastava, M.M. 1990. Eco-physiological response of Pisum sativum and Citrus maxima to distillery effluents. Int J Econ Environ Sci 16–23

Rossetto, R.,. Dias, F. L. F., Vitti, A. C., Cantarella, H. and Landell, M. G. A. 2008. “Manejo conservacionista e reciclagem de nutrientes em cana-de-açúcar tendo em vista a colheita mecânica,” Informações Agronômicas, no. 124, pp. 8–13,

Samuels, G.1980. Distillery wastes: potential agricultural and industrial uses in Puerto Rico. P R Sugar J.; 43:9–12.

Silva, M. A. S.,Griebeler, N. P and Borges, L. C. 2007. "Uso de vinhaça e impactos nas propriedades do solo e lençol freático," Revista Brasileira de Engenharia Agrícola e Ambiental, vol. 11, no. 1, pp. 108–114,.

Singh, A.B., Biswas, A.K and Ramana, S. 2003. Effect of distillery effluents on plant and soil enzymatic activities and groundnut quality. J Plant Nutr Soil Sci.; 166:345–347. doi: 10.1002/jpln.200390053.

Su, T.M.,. Li, Y.R ., Wei, G.P and Jiang, Z.P. 2009. Effect of sugarcane vinasse on soil physicochemical properties and oxidoreductase enzymes. Chinese Journal of Eco-Agriculture 6: 1106–1110