Journal of Technology and Value Addition, Volume 3 (1), 2021: (75-88)

Research Article

Production of Organic Fertilizers by Using Sugarcane Industry By-products of Sri Lanka: A Preliminary Investigation

B.R. Kulasekara[1*], H.A.S. Weerasinghe[1], B.D.S.K. Ariyawansha[1]

* kulasekaraya@gmail.com

[1]Sugarcane Research Institute, Uda Walawe, Sri Lanka

Abstract

Utilisation of the sugarcane industry by-products in Sri Lanka has immense potential. Hence, this preliminary investigation was conducted to find out the feasibility to produce organic fertiliser from the sugarcane industry by-products and to evaluate their nutritional characteristics favourable for sugarcane plant growth. Two consecutive experiments were included in the study. First, the organic fertiliser preparation experiment included 4 different mixtures of sugarcane trash, filter-mud and vinasse up to two months. The following pot experiment along with sugarcane variety SL 96 128 was conducted up to 3 months compared with 5 treatments that 3 types of organic fertiliser mixtures (OFMs) in 20 ton/ha level along with half of the recommended chemical fertilisers (CF), recommended CF and zero fertiliser (control). The results indicated that incorporation of trash slow down the decomposing process and the using only filter-mud and vinasse is more effective in organic fertiliser preparation and they are rich in macro and micro plant nutrients. According to pot culture, there is no phytotoxic effect on sugarcane plants from OFMs. Both soils that OFM (20 ton/ha) + half of recommended CF and recommended CF added are similarly rich in major plant nutrients. Plant height, shoot dry weight and total dry weight shows significant differences compared to the control. Meanwhile, the filter-mud and vinasse based OFM + half of recommended CF applied plants and recommended CF applied plants perform similarly in growth. Thus, the feasibility to use of sugarcane by-products to minimise chemical fertilisers in sugarcane cultivation is at a remarkable level.

Keywords: *Sugarcane by-products, organic fertiliser, vinasse, filter-mud*

1. Introduction

The process of sugar manufacturing in Sri Lanka generates by-products namely, bagasse, fly-ash, molasses, filter-mud and vinasse. Molasses is further utilised in the process of producing ethanol and releases another by-product named vinasse. Apart from that, the dried leaves left on the field at harvesting named trash.

The Sri Lankan sugar industry is well described in Figure 1 where bagasse is employed for the cogeneration process with the factory level self-sufficiency in energy (Keerthipala, 2016). Sugarcane filter-mud is a residue coming out from the sugar manufacturing process. During the clarification process, the clear sugarcane juice is separated and the residue is removed as filter-mud (Diaz, 2016). It is a rich source of phosphorus and organic matter with the level of moisture content (Sardar *et al*., 2012). Vinasse is an aqueous effluent of the distillation unit in the sugar-alcohol industry comprising mainly of water, organic matter and mineral elements (Pandey *et al*., 1995). However, filter-mud and vinasse are not efficiently utilised in Sri Lanka.

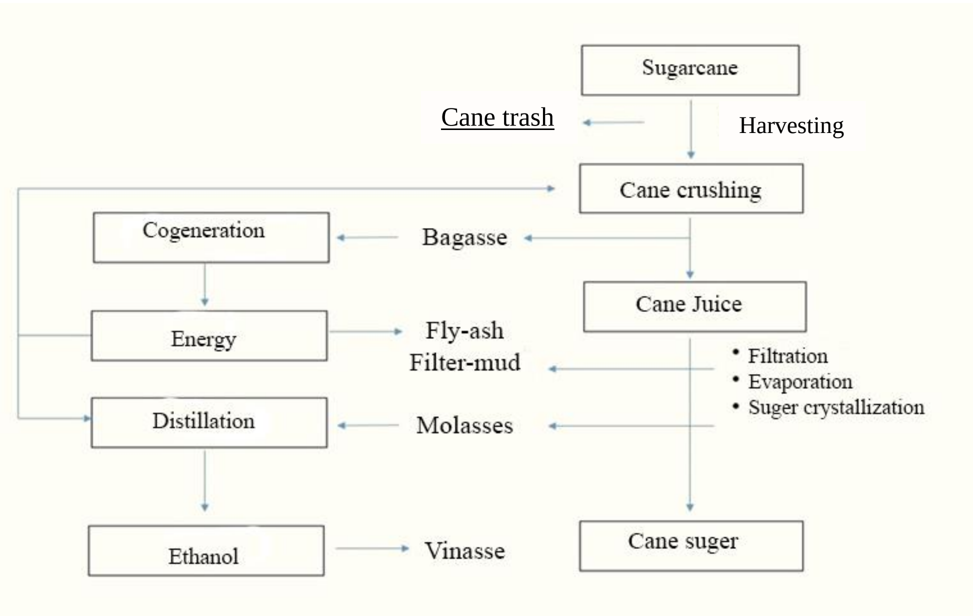

Figure 1: By-products generation in sugarcane industry

The production of organic fertilisers by using cane trash, filter mud and vinasse is becoming an interesting field with efficient product cycling (Diaz, 2016). Under the Sri Lankan cane sugar industry capacities, there also have a better potential for organic fertiliser preparation by using its own by-products (Keerthipala, 2016). Hence, the identification of a well-planned and technically proven method for organic fertiliser preparation is highly required. Further, it can be used as a substitution for inorganic fertilisers.

There are three functioning sugar-producing industries in Sri Lanka namely, Sevanagala, Pelwatte and Hingurana having processing capacities of 1250 TCD (Tonnes of cane per day), 3300 TCD and 2000 TCD respectively. Each mill has a distillery plant with the capacities of 60 TMD (Tonnes of molasses per day) at Sevanagala, 100 TMD at Pelwatta and 30 TMD at Hingurana (Keerthipala, 2016). At the factory level, one ton of cane averagely produces 30-35 kg of filter-mud and 140-160 l of vinasse as by-products under Sri Lankan scenarios. A factory equipped with 1000 TCD capacity, functioning for 240 days per year will generate 7200 tons of filter-mud and a distillery equipped with 50 TMD capacity, functioning for 240 days per year will generate 48000 m^3 of vinasse averagely. Hence, there is a good potential for the production of organic fertilisers from the sugarcane industry by-products of Sri Lanka.

Organic fertiliser reduces the dependency on chemical fertilisers and provides the best solution for the higher cost of fertiliser in agriculture. The amendment of organic matter to the soil improves the physical, chemical and biological properties of the soil and it is directly affected to the final yields and quality parameters of a crop. In sugarcane plant nutrition, recycling of nutrients is more important as a large amount of nutrient flush is removed from the field at cane harvesting. In Sri Lanka, intensive sugarcane cultivation in the time of more than thirty years requires such an organic fertiliser to maintain its soil quality. Hence, this preliminary investigation was conducted to find out the feasibility of organic fertiliser production from sugarcane industry by-products, assessment of the nutritional status of organic fertilisers and to evaluate the performance of different fertiliser mixtures in early growth stages of sugarcane.

2. Materials and Methods

The study consisted of two consecutive experiments. The first experiment was to identify the succession pattern of sugarcane by-product decomposing and identify the levels of nutrients in predetermined organic fertiliser mixtures (OFM). The second experiment was a pot culture, planted with sugarcane to evaluate the performance of selected organic fertiliser mixtures in plant nutritional aspects. Both experiments were conducted at Sugarcane Research Institute (SRI) of Sri Lanka, Uda Walawe located at 6°24'N, 80°49'E and 74 m above sea level.

2.1 Experiment 01 – Organic Fertiliser Preparation Experiment

The production of organic fertilisers was conducted by using sugarcane trash, filter-mud and vinnase as input substances. Sugarcane trash were collected from SRI - sugarcane fields and filter-mud and vinnase were collected from the factory of Lanka Sugar Company (Pvt) Ltd, Sevanagala unit. The input substances were analysed for chemical properties before starting the organic fertiliser preparation process. Undisturbed topsoil sample collected from near to the Walawe river bank was incorporated to the decomposing process as a microbial inoculant.

Four treatment combinations were established with three replicates in a Randomized Complete Block Design (RCBD) to study the decomposing process of sugarcane trash, filter-mud and vinnase (Table 1).

Table 1: Treatment combinations of sugarcane trash, filter-mud and vinnase

Treatments / Organic fertiliser mixture (OFM)	Trash: Filter-mud ratios (weight basis)		Vinnase amount applied initially and at every turning-over (litres)
	Trash	Filter-mud	
OFM – 1	2	5	4
OFM – 2	1	5	4
OFM – 3	1	10	4
OFM – 4	0	1	4

2.2 Preparation and Maintenance of Decomposing Piles

The piles were prepared by adding decomposing substances in layer-wise. The area of the pile was 1 m^2 and height ranged from 1.2-1.5 m. The pile preparation was started by a layering of coarse plant parts (cane stalks) for proper air circulation and facilitate excess water flow. The following successive layers of input substances were piled on top of the coarse plant parts. As per the treatment mixtures, a layer of sugarcane trashes up to 10 cm thickness, a layer of filter-mud up to 10 cm thickness and a thin layer of undisturbed topsoil up to 1 cm thickness were loaded respectively. The ordering was repeated as per the treatment combinations. Prior to loading sugarcane trash, they were cut into small pieces before addition. After completion of piling, the predetermined amount of vinasse (4 l) was sprinkled uniformly. Piles were turned over regularly to maintain correct air circulation and moisture.

The turning over of the piles was done at 2 weeks, 3 weeks and 5 weeks after piling. The optimum moisture level of the decomposing piles was visually observed by squeezing a mixture firmly in the hand-palm, and no water comes out of the fingers. The formed ball should collapse easily when open the palm. Throughout the process, the temperature readings were recorded in each pile with timely and graphed temperature variations to identify the decomposition pattern of each treatment combinations. At the end of the decomposing process, after 2 months, decomposed materials were sieved and separated organic fertiliser mixtures as per the pre-introduced treatment combinations. After that, composite samples of each organic fertiliser mixtures were analysed for their chemical properties including pH, Electrical conductivity (EC), Total Nitrogen (N), Available phosphorous (P,) exchangeable potassium (K), calcium (Ca), Magnesium (Mg), copper (Cu), manganese (Mn) and zinc (Zn) contents.

2.3 Experiment 02 – Pot Experiment

In the second experiment, single bud sets of sugarcane (Saccharum hybrid spp.) variety SL 96 128 were grown in pots under net house condition. Soils used for pot experiment were collected from the research farm of SRI and analysed to determine initial nutrient levels prior to apply treatments.

Five treatment combinations including three mixtures selected from the first experiment were tested in the pot experiment with three replicates in a RCBD (Table 02).

Table 2: Treatment combination levels of the pot experiment

Treatment number	Treatment combinations
Treatment 1	OFM - 2 (20 ton/ha) + 50% of SRI N:P:K recommendation
Treatment 2	OFM - 3 (20 ton/ha) + 50% of SRI N:P:K recommendation
Treatment 3	OFM - 4 (20 ton/ha) + 50% of SRI N:P:K recommendation
Treatment 4	SRI N:P:K recommendation (N-138 kg/ha, P_2O_5-90 kg/ha, K_2O-135 kg/ha)
Treatment 5	Zero fertiliser (control)

At the completion of 3 months after planting, the number of tillers and leaves of sugarcane plants were recorded. Then, plants were uprooted and oven-dried at 70 ℃ until getting a constant weight to determine shoot dry weight (SDW), root dry weight (RDW) and total dry weight (TDW) of plants. Moreover, soil samples collected from each pot were also analysed for soil pH, EC, Total N, Available P and exchangeable K.

2.4 Soil and Organic Fertiliser Analysis

Composite samples of soils and organic fertilisers were analysed for their chemical properties by following standard analytical procedures. The dry ash method was followed for organic fertiliser analysis with a muffle furnace. The chemical parameter, pH was measured by 1:2.5 soils to distilled water ratio method using a pH meter (Adwa-AD1030) with glass electrodes. EC was measured by 1: 5 soils to distilled water ratio, suspension method using a conductivity meter (TOA-CM20S). Standard Kjeldhal procedure was followed for total N analysis with the modified colourimetric method by using UV-VIS - spectrophotometer (UV-2600-Shimadzu). The available P was analysed through standard Olsen method followed by 0.5 M NaHCO3 extraction with Ammonium Molybdate and Ascorbic by modified colourimetric method using UV-VIS - spectrophotometer (UV-2600-Shimadzu). The exchangeable K, Ca, Mg were analysed through ammonium acetate extraction method using the Atomic Absorption Spectrophotometer (AA 6300). The available Zn, Cu and Mn were analysed through diethylenetriaminepentaacetic acid (DTPA) extraction method using the Atomic Absorption Spectrophotometer (AA 6300). The analysis of organic carbon content followed by Walky and Black method.

2.5 Data Analysis

The effects of treatment combinations were compared by analysis of variance (ANOVA) in both experiments. The treatment means were separated by Duncan's procedures against to the control at 5% probability level. Data were analysed by using PROC ANOVA procedure of SAS statistical software. Both data sets were checked for normal distribution prior to analysis using Anderson darling test and tested for out liars using Grub's method (Grubs, 1950).

3.Results and Discussion

3.1 Experiment 01:

Before starting the organic fertiliser preparation, the initial chemical characteristics of sugarcane trash, filter-mud and vinasse are shown in Table 3.

Table 3: Chemical characteristics of input substances used for organic fertiliser preparation

Input substance	pH	EC (mS/cm)	Organic carbon%	Nitrogen%	Phosphorus %	Potassium %
Vinasse	4.5	39.8	3.1	0.13	0.03	0.67
Filter-mud	7.8	1.5	10.9	0.27	0.27	0.06
Cane-trash	-	-	-	1.65	0.15	1.54

The results revealed that vinasse is an acidic substance with 4.5 pH level. The low pH of the vinasse is attributed to the presence of high amount of sulphate, sulphur as per the distillery process. Further, it is rich in potassium with a considerable amount of organic carbon content (Hati *et al*., 2007). The pH of filter-mud was in the alkaline range and showed lower EC compared to the vinnase. Filter-mud was consisted of more organic carbon content comparative to vinasse and it contained more phosphorous and nitrogen compared to the potassium. Out of three input substances, filter-mud was the highest P inclusion material (Prado *et al*., 2013). Cane trash were only analysed for its N, P and K contents and the results were comparable to the average nutrients contents of the sugarcane plant leaf (Calcino, 2010).

3.2 Temperature Variations during the Decomposing Process

The process of organic fertiliser preparation was continued throughout 2 months' time period. The average temperature variations with time in every decomposing pile are depicted in the Figure 2. A good decomposing process should pass through four consecutive stages *i.e.*, warming-up, heating (Thermophilic), cooling (Mesophilic) and maturing phases (Van der Wurff *et al*. 2016). However, the patterns of temperature variations of treatments were different from each other as per the initial composition of input substances.

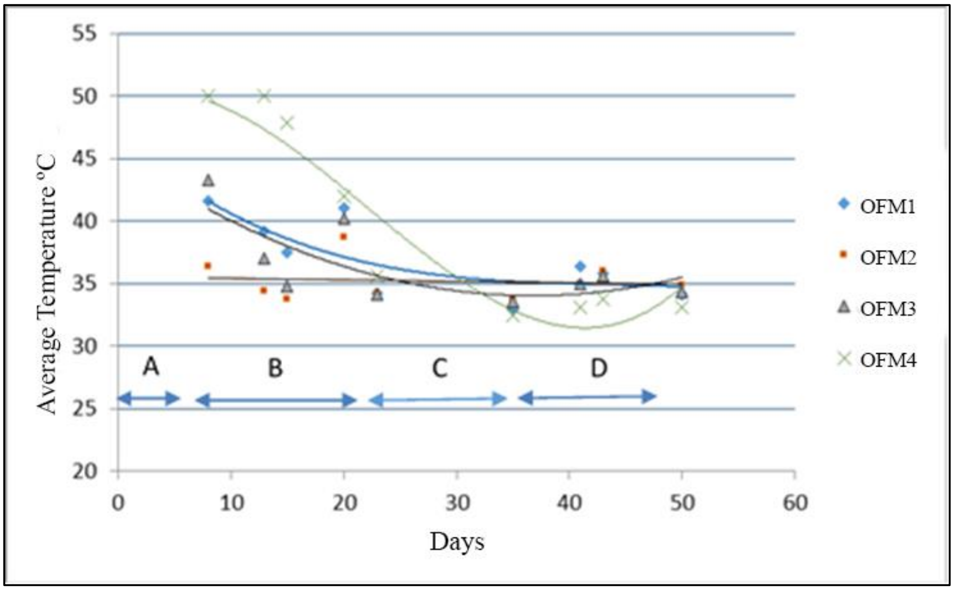

Figure 2: Temperature variations during the organic matter decomposition (A - Warming-up phase, B – Heating phase, C – Cooling phase and D – Maturing phase)

During the warming-up phase, the temperature inside the decomposing piles begins to rise with increased microbiological activity under favourable conditions, especially correct pH, moisture and air. Further, the starting mixture has to have an adequate C/N ratio between 25 and 35 for a good decomposing process (Van der Wurff *et al*., 2016).

The decomposition process leads to produce more heat energy in the heating phase rapidly. The temperature in the middle of the decomposing pile should reach up to 65°C and even 70°C if the process continued properly (Van der Wurff *et al*., 2016). However, except for OFM - 4, the other three treatments did not show a correct thermophilic phase induction by attaining 45-60°C temperature range. It indicates that, the other three treatment combinations showed lower decomposition performances comparatively.

After the heating phase, microbial degradation slows down significantly and become to the cooling and maturation phases (Van der Wurff *et al*., 2016). The results further indicated that only OFM - 4 showed the typical pattern of temperature variations of organic matter decomposition and has successfully reached four consecutive phases. Except OFM -4, other three OFMs contained trash as raw material. This clearly exhibited that, the incorporation of sugarcane trash, reduces decomposing rate and deviates from typical pattern of decomposition. This can be affected to the final quality of the end product of any type of organic fertiliser. Results further indicated that incorporation of trash slows down the decomposing process, hence using only filter-mud and vinasse is more effective than other OFMs.

3.3 Chemical Properties of Prepared Different Organic Fertiliser Mixtures

The produced organic fertiliser mixtures showed specific good characteristics such as earthy smell without any unpleasant odour, a cooler condition in the heap without heating up and good in colour as reported in previous literature (Diaz, 2016). The chemical properties of prepared four types of organic fertiliser mixtures are depicted in table 4.

Table 4: Chemical characteristics of prepared different organic fertiliser mixtures.

Prepared OFM	Chemical parameters									
	pH	EC (mS/cm)	N%	P%	K%	Mg%	Ca%	Mn (ppm)	Zn (ppm)	Cu (ppm)
OFM 1	8.28	2.50	0.937	0.470^{b}	0.597	0.363	1.873^{b}	684.5^{a}	155.9	38.8
OFM 2	8.19	2.17	0.693	0.323^{c}	0.546	0.387	1.667^{b}	803.9^{a}	151.2	38.0
OFM 3	8.15	2.84	1.030	0.603^{ab}	0.570	0.413	2.367^{ab}	784.6^{ab}	158.8	38.8
OFM 4	8.21	2.69	1.153	0.707^{a}	0.470	0.463	2.840^{a}	616.3^{b}	166.0	41.5

Different superscript simple letters are showing significant difference at $P<0.05$

According to the results, when comparing the nutrient status of prepared different OFMs, only P, Ca and Mn contents were showed a significant difference among OFMs and the probability values were $p= 0.001$, $p= 0.032$ and $p= 0.021$ respectively. No significant difference was observed in other chemical parameters among tested OFMs.

The highest P and Ca contents were recorded in OFM - 4. However, the highest and lowest Mn content was recorded in OFM - 2 and OFM – 4 respectively. When considering other chemical parameters, the highest N, Mg, Zn and Cu contents were also recorded in OFM - 4. The lowest K content was recorded in OFM - 4 and the highest K content was recorded in OFM - 1. All four OFMs were in good pH range without being more acidic or alkaline. However, the highest pH was recorded from OFM - 1 with higher amounts of trash than that of other combinations. EC values of OFMs were also in a good range without saline effect. When considering all consequences regarding the chemical parameter analysis of prepared OFMs and their decomposing patterns, OFM – 4 showed the best characteristics compared to a good organic fertiliser. Under these circumstances, when selecting OFMs for the experiment – 2 (pot experiment), OFM - 1 with comparatively higher amount of trash incorporated combination (2:5 in the trash: filter-mud) was not considered according to its initial decomposing pattern, chemical and quality characters of the end product.

3.4 Experiment 02:

3.4.1 Initial Soil Analysis before the Pot Experiment

The collected soils from the SRI research farm for the pot experiment belonged to the Reddish Brown Earth (RBE) soil category and the average chemical properties were as follows (Table 5).

Table 5: Initial chemical properties of the soils used for pot experimental soils

Soil parameter	Amount/level
pH	7.71
Electrical conductivity (mS/cm)	0.14
Total Nitrogen (mg/kg)	667.1
Available Phosphorous (mg/kg)	29.7
Exchangeable Potassium (mg/kg)	447.1

The chemical parameters of the collected RBE soil were similar to the parameters highlighted for RBE soil by Mapa *et al*., (2010).

3.4.2 Soil Analysis of the Pot Experiment at Three Months after Planting

The chemical properties of the pot experimental soils at three months after planting is depicted in the table 6. When comparing, initial results with the results obtained three months after treatments application, it was observed that soil N, P and K contents except in the treatment 5(control) have been increased. These increased N, P and K levels could be due to adding different organic manures. In the control, P and K levels had been decreased and only N content had been increased slightly.

Table 6: Chemical characteristics of pot experimental soils three months after planting

Treatments	Soil chemical characteristics				
	pH	EC (mS/cm)	N (mg/kg)	P (mg/kg)	K (mg/kg)
Treatment 1	7.36	0.16[b]	1711.9	62.3	445.9
Treatment 2	7.32	0.18[a]	1602.4	18.4	382.4
Treatment 3	7.44	0.20[a]	1788.9	39.9	420.6
Treatment 4	7.39	0.15[bc]	1892.6	47.9	440.9
Treatment 5	7.47	0.13[c]	1381.1	15.5	394.3

Different superscript simple letters are showing significant difference at $P < 0.05$, T1 - OFM - 2 (20 ton/ha) + 50% of SRI N:P:K recommendation, T2 - OFM - 3 (20 ton/ha) + 50% of SRI N:P:K recommendation, T3 - OFM - 4 (20 ton/ha) + 50% of SRI N:P:K recommendation, T4 - 100% of SRI N:P:K recommendation, T5 - Zero fertiliser (control)

Soil EC was the only soil parameter which showed significant changed with the amendment of different fertiliser mixtures into the soil ($p= 0.0009$). The highest EC was recorded from the treatment 3, which contained OFM - 4 (20 ton/ha) and 50% of SRI recommended N: P: K levels. The lowest soil EC was recorded from the treatment 5 (control) that was the zero-fertiliser treatment. The recorded EC values indicated that, with the increasing of the proportion of filter-mud in OFMs, the EC values have also been increased gradually. With the amendment of different fertiliser combinations, the other soil chemical parameters were not significantly different among the treatment combinations.

In this context, results of soil chemical parameter analysis at three months after planting revealed that the organic fertilisers (20 ton/ha) + 50% of SRI recommended N: P: K level amended soils and 100% of SRI recommended N: P: K level added soils are similarly rich in major plant nutrients. Thus, it gives a positive fact regarding the minimum dependence on chemical fertilisers in sugarcane cultivation. However, these results are only confined to three months of a pot experimental soils. Hence, it is more required field level studies to confirm findings.

3.5 Sugarcane Plant Growth Performance under Different Fertiliser Combinations

With the amendment of organic fertiliser mixtures, there was no any observed phytotoxic effect on sugarcane plants. There was no significant difference in the recorded number of sugarcane tillers and leaves of sugarcane plants at three months after planting, However, there was a significant difference in plant heights among the treatments ($p= 0.021$). The mean plant heights relevant to the different fertiliser treatments at three months after planting are depicted in figure 3.

The lowest plant height was recorded from zero fertiliser level treatment and highest plant heights were recorded from the treatments 3 and 4 that OFM - 4 (20 ton/ha) + 50% of SRI recommended N: P: K levels and 100% of SRI recommended N: P: K levels, respectively.

However, there was no significant difference of plant height between these two treatments. Hence, these results indicated that the reduction of 50% of chemical fertilisers along with a suitable organic fertiliser is applicable and it shows similar performance as the 100% of SRI recommended N: P: K levels during first three months planting period. For the confirmation of this finding, it is also required enough field-level evidence regarding the organic fertiliser use and plant growth attributes.

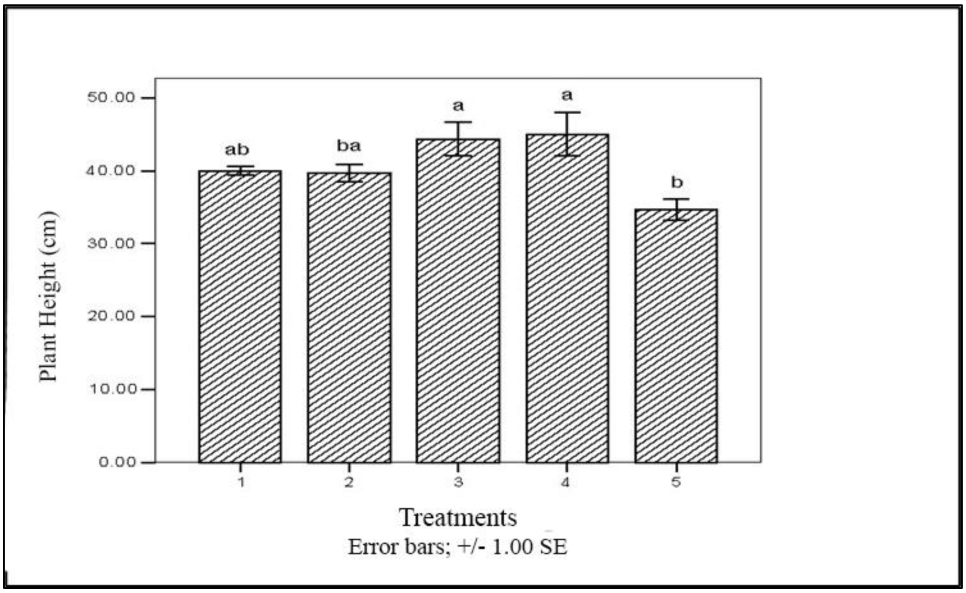

Figure 3: Mean plant height of sugarcane at 3 months after planting. Different simple letters are showing significant difference at $p < 0.05$. T1 - OFM - 2 (20 ton/ha) + 50% of SRI N:P:K recommendation, T2 - OFM - 3 (20 ton/ha) + 50% of SRI N:P:K recommendation, T3 - OFM - 4 (20 ton/ha) + 50% of SRI N:P:K recommendation, T4 - 100% of SRI N:P:K recommendation, T5 - Zero fertiliser (control).

The average values of SDW, RDW and TDW of pot cultured sugarcane at three months after planting time are shown in Figure 4.

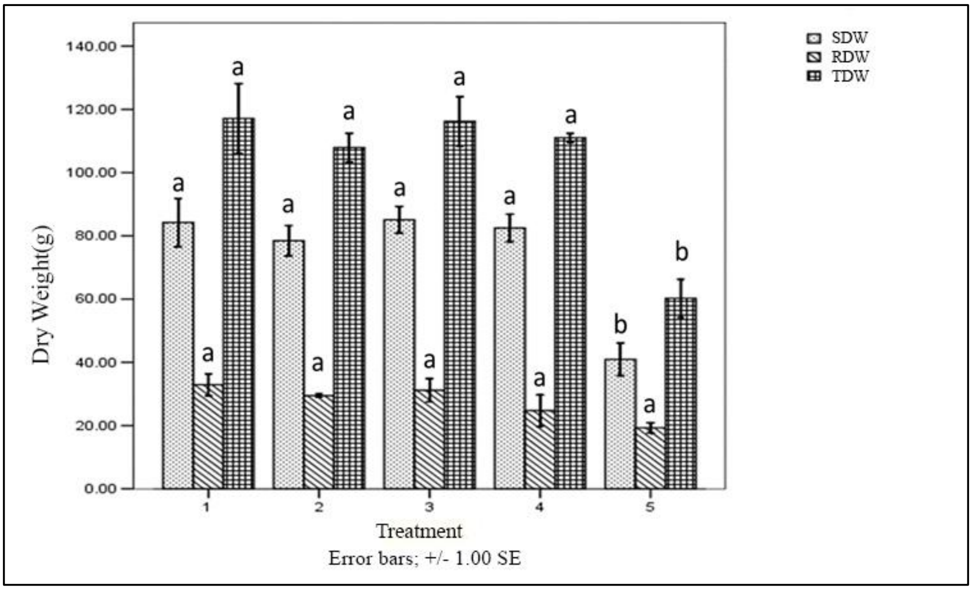

Figure 4: Mean dry weight values of sugarcane shoots, roots and total plant at 3 months after planting. Different simple letters are showing significant difference at $p < 0.05$. T1 - OFM - 2 (20 ton/ha) + 50% of SRI N: P: K recommendation, T2 - OFM - 3 (20 ton/ha) + 50% of SRI N: P: K recommendation, T3 - OFM - 4 (20 ton/ha) + 50% of SRI N: P: K recommendation, T4 - 100% of SRI N: P: K recommendation, T5 - Zero fertiliser (control)

The results showed that only SDW and TDW values of sugarcane plants were highly significant among the treatments with the probability values, $p = 0.0032$ and $p= 0.0031$ respectively. There was no significant effect on RDW values of sugarcane plants from different treatment combinations. According to the chemical parameters of the pot experimental soils before adding treatment, there was an averagely good nutritional soil (Table 5) for a three months' time pot experiment. Hence, even though, the Lowest RDW was recorded from the control there had been enough soil nutrients for the initial root development. However, the filter-mud and vinasse based organic fertiliser + 50% of the recommended N: P: K applied plants were grown well same as the recommended N: P: K applied plants without a significant difference.

4. Conclusions

The results of the study showed that sugarcane filter-mud and vinasse are averagely rich plant nutrient sources and there is a potential to use them as organic amendments in sugarcane farming. Hence, the production of organic fertilisers from the sugarcane industry by-products is a realistic and proven process under Sri Lankan scenarios. The study further revealed that the incorporation of sugarcane trash for the organic fertiliser production process is lengthening the decomposing process. However, the use of filter-mud with vinasse is more successful and within

60 days, the whole degradation process can be completed efficiently. Moreover, the analytical results of organic fertiliser also indicated that the filter-mud and vinasse based organic fertiliser mixture is rich in plant macro and micronutrients and also maintain preferable soil pH level. It does not create any adverse effect on the growth of sugarcane plants as well. Moreover, this study revealed that there is a feasibility to minimise chemical fertilisers in sugarcane cultivation to a greater extent. However, further field studies are needed to confirm findings.

5. Acknowledgement

We wish to express our deepest gratitude to the former Director, Dr. A. P. Keerthipala and the present Acting Director, Dr. M.S. Perera of Sugarcane Research Institute, for their valuable guidance. Furthermore, we extend our deepest appreciation to all the research and technical staff of the division of Crop Nutrition.

6. References

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

Calcino, D.V., (2010). Australian Sugarcane Nutrition Manual, BSES Limited Technical Publication MN10004.

Cassman, K.G., (1999). Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. Proceedings of the National Academy of Sciences USA 96, 5952-5959.

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.

Dharmawardene, M.W.N., (2004). Sri Lanka sugar soils and their assessment. Sugarcane Research Institute, Uda Walawe. pp.1-61.

Diaz, P.M., (2016). Consequences of compost press mud as fertilisers. *DJ International Journal of Advances in Microbiology and Microbiological Research*, 1(1), 28-32.

Grubbs and Frank, E., (1950). Sample criteria for testing outlying observations". *Annals of Mathematical Statistics*. 21 (1), 27–58.

Hati, K.M., Biswas, A.K., Bandyopadhyay, K.K. and Misra, A.K., (2007). Soil properties and crop yields on a vertisol in India with application of distillery effluent. *Soil & Tillage Research*, 92, 60–68.

Hati, K.M., Swarup, A., Dwivedi, A.K., Misra, A.K. and Bandyopadhyay, K.K., (2007). Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring. *Agriculture, Ecosystems. Environment* ,119, 127-134.

Haug, R.T., (1980). Compost engineering principle and practice (pp. 655). Ann Arbor Science Publishers Inc.

Keerthipala, A.P., (2016). Development of sugar industry in Sri Lanka. *Sugar Tech (Nov-Dec),* 18(6),612–626.

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.

Mapa, R., Somasiri, S. and Dassanayake, A.R., (2010). Soils of the dry zone of Sri Lanka - Morphology, Characterisation and Classification (pp. 319). Sarvodaya Publishers, Sri Lanka.

Masato, N., Kazunori, I. and Yoshito, Y., (2005). Toward the holistic use of biomass resources (2). Composting technology. *Journal of the Japanese Society of Irrigation, Drainage and Reclamation Engineering*,73 (7), 617-622.

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

Prado, R.D.M., Caione, G. and Campos, C.N.S., (2013). Filter cake and vinasse as fertilisers contributing to conservation agriculture. *Appl Environ Soil Sci*, 1-8.

Sharma, V.K., Canditelli, M., Fortuna, F. and Cornacchia, G., (1997). Processing of urban and agro-industrial residues by aerobic composting: Review. *Energy Conversion and Management*,38 (5), 453-478.

Sardar, S., Ilyas, S.U., Malik, S.R. and Javaid, K., (2012). Compost fertilizer production from sugar press mud (SPM). *International Journal of Energy and Environmental Engineering*, 3(1), 39-43.

Sindhu, S.K., Sharma, A. and Ikram, S., (2007). Analysis and recommendation of agri-culture use of distillery spent-wash in Rampur District, India. *E-Journal of Chemistry*, 390-396.
Available from: http://www.e-journals.net 4

Van der Wurff, A.W.G., Fuchs, J.G., Raviv, M. and Termorshuizen, A.J., (2016). Handbook for Composting and Compost Use in Organic Horticulture Bio Greenhouse COST Action FA 1105, www.biogreenhouse.org.