Eco. Env. & Cons. 28 (January Suppl. Issue) : 2022; pp. (S262-S268)

ISSN 0971–765X

http://doi.org/10.53550/EEC.2022.v28i01s.037

Recycling of Biomethanated Distillery Spent wash to enhance soil health, growth and Yield of Sugarcane

R. Jayashree, K. Suganya and V. Sathyasree

Department of Soils and Environment
Agricultural College and Research Institute, Madurai 625 104, T.N., India

(Received 16 August, 2021; Accepted 14 September, 2021)

ABSTRACT

Sugar industry is the second largest agro-based industry in India, which contributes substantially to the economic development of the country. The distillery units mainly use sugarcane molasses as a preferred raw material and for every liters of alcohol production, 10-15 liters of waste water, known as spent wash, is generated which poses serious disposal problems. Field experiment was conducted to study the efficiency of Biomethanated distillery spentwash, on improving the yield and quality of Sugarcane at Research and Development farm of Bannari Amman Sugars Ltd., Modur, Sathyamangalamtaluk, Erode district, using Sugarcane, Co 86032 as a test variety with a spacing of 40cmx30cm. Application of 40KL + Biocompost (1.0 tonnes) (T_5) recorded higher yield of 76 t ha^{-1}, + NPK as per recommended dose (T1) recorded the lower yield of 53 t ha^{-1}.Increase in the rate of spentwash application markedly increased the Exchangeable Ca, Mg, Na, K concentration and relatively higher values were observed in soil that received 40kl spentwash with 1 tonnes of biocompost. Mineralization of organic matter and the nutrients present in the effluent are responsible for the increase in the availability of nutrients in soil.

Key words : *Distillery spentwash-Application-Sugarcane-Soil Nutrients-Growth-Yield*

Introduction

In India, alcohol (ethanol) is produced mainly by the fermentation of diluted sugarcane molasses. After fermentation, the alcohol is separated by distillation and the residual liquid in large volumes (for every litre of alcohol produced 15 litres of waste liquid) is discharged as wastewater, generally known as spentwash. Although different terminologies *viz.,* stillage, vinasse, slop, bottom slop, still residue are used for this type of effluent in different countries, the term spentwash is usually referred for distillery effluent. Molasses is used as raw material for the production of alcohol in most of the Indian distilleries. The molasses is diluted to 12 to 20 per cent water, inoculated with yeast and allowed to ferment for 5 to 12 hours at 30 ^{o}C. In the production of alcohol from molasses, 3 to 10 kg of molasses is used for producing one litre of alcohol (Joshi, 2001).

Unlike other industrial wastes, the waste products of sugar and molasses based distillery industries do not contain any hazardous materials that are detrimental to soil health and plant growth because during the process of sugar production and molasses fermentation expect sulphur, lime and sulphuric acid, no other extraneous inorganic or organic chemicals are added. However, a very high Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), significant quantity of trace elements (Cd, Cu, Fe, Mn, Ni and Zn) are contributed

(Assistant Professor (ENS))

from sugarcane molasses originated from plant extract and during the industrial process of alcohol productions, land disposal of effluent with proper management technologies could be thought of as an alternative for reducing pollution hazard and improving the crop productivity as the treated spent wash contains considerable amount of N and P, rich in K, Ca, Mg, and SO_4 and trace amounts of Zn, Cu, Fe and Mn Rajagopal *et al*., 2014; Pugazh *et al*., 2016). Utilization of industrial effluent after proper treatment in agriculture has raised the hope of recycling the effluent in constructive way. The research on spentwash application in agriculture confirms the potential benefits of biomethanated spentwash (Chandraju *et al*., 2013). The spentwash can increase the chlorophyll content and ultimately plant growth (Chpra *et al*., 2013). Sugarcane is a cash crop requires high amount of nutrients, particularly K. Local farmers are not able to bear the cost of fertilizers and this led to poor yield of sugarcane. The waste water coming out of sugar industry biomethanated spentwash can supplement the requirements of farmers by way of application of spentwash without deteriorating soil health. Biocompost produced from pressmud waste composting is also helps to enhance the soil health. Hence, the present research aims to recycle the spentwash for supporting the soil health along with biocompost prepared in Bannari Amman sugars and tested its ability to enhance the growth and yield of sugarcane.

Materials and Methods

Field Experiment

Field experiment was conducted to study the efficiency of Biomethanated distillery spentwash, on improving the yield and quality of Sugarcane at Research and Development farm of Bannari Amman Sugars Ltd., Modur, Sathyamangalamtaluk, Erode district, Tamil Nadu in Randomized Block Design with three replications using Sugarcane, Co 86032 as a test variety with a spacing of 40cmx30cm. The treatment details are as follows, T1 : Control (Recommended dose of NPK), T2 : 40KL + NP as per recommended dose,T3 : 30KL + NP as per recommended dose,T4 : 20KL + NP + 50 % K as per recommended dose,T5 : 40KL + Biocompost (1.0 tonnes) T6 : 30KL + Biocompost (1.5 tonne),T7 : 20KL + Biocompost (2 tonnes). Five canes were randomly selected and marked separately for measurement of growth parameters. Plant height and internode length were recorded using a measuring tape, number of internodes were counted in each plant. Yield was measured by weighing the canes in each plot.

Sampling of spentwash and processing of soil samples

Spent wash samples were collected from Bannari Amman sugar mills and analysed physico chemical charecteristics as per standard methods (APHA, 1998). Soil sample was collected initial, 6^{th} month and harvest stages of crop growth. The collected soil samples were air dried, powdered with wooden hamlet and sieved through 2 mm sieve and used for further analysis (Table 1).

Results and Discussion

Spentwash charecteristics: The PMDSW was dark brown in colour with an unpleasentodour of burnt sugar. It carries large amount of Total Suspended Solids (9259 mg L^{-1}), Total Dissolved Solids (39160 mg L^{-1}), Total Solids (45638 mg L^{-1}), BOD (7217 mg L^{-1}) and COD (36519 mg L^{-1}). The PMDSW was slightly alkaline in pH (7.42) with an EC of 32.5 dSm^{-1} and organic carbon 13.7 per cent. Among the major plant nutrients, potassium was found in higher amounts (10513 mg L^{-1}) followed by nitrogen (1760

Table 1. Analytical methods followed for soil quality parameters

S. No	Properties	Method	Reference
1	pH	pH meter	Jackson (1973)
2	EC	Conductivity meter	Jackson (1973)
3	Organic Carbon	Wet Digestion method	Walkley and Black (1934)
4	Available Nitrogen	Alkali permanganate method	Subbiah and Asija (1956)
5	Available Potassium	Flame photometer	Jackson (1973)
6	Exchangeable Calcium	Neutral normal ammonium acetate	Jackson (1973)
7	Exchangeable Magnesium	Neutral normal ammonium acetate	Jackson (1973)

mg L^{-1}) and phosphorus (149 mg L^{-1}) (Table 2). Spentwash had the highest organic N content with BOD and COD in the range of 45 to 55 and 90 to 110 kg m^{-3}, respectively. Among the nutrients, K was present in highest concentration which ranged from 6.0 to 8.0 kg m^{-3} (Mohan Naidu, 2002). Distillery effluent contained large amounts of organic matter, N, P, K, S, and Ca along with high salt load. Sulfates and chlorides of K, Na and Ca were dominant and it also contained sugar and proteins to the extent of 2 to 20 per cent and 10 to 11 per cent, respectively (Kanimozhi, 2010).

Table 2. Characteristics of Post Biomethanated Distillery Spentwash (PMDSW)

Parameters	Value
Colour	Dark brown
Odour	Unpleasant
Moisture (per cent)	87.1
Specific gravity (g cc^{-1})	1.14
pH	7.42
EC (dS m^{-1})	32.5
Total Suspended Solids (mg l^{-1})	9259
Total Dissolved Solids (mg l^{-1})	39160
Total Solids (mg l^{-1})	45638
Organic Carbon (per cent)	13.7
BOD (mg l^{-1})	7217
COD (mg l^{-1})	36519
Nitrogen (mg l^{-1})	1760
Phosphorous (mg l^{-1})	149
Potassium (mg l^{-1})	10513
Calcium (mg l^{-1})	2161
Magnesium (mg l^{-1})	1422
Sodium (mg l^{-1})	657
Chloride (mg l^{-1})	9400
Carbonate (mg l^{-1})	Nil
Bicarbonate (mg l^{-1})	126.675
Sulphate (mg l^{-1})	72.135
Iron (mg l^{-1})	84.91
Manganese (mg l^{-1})	8.965
Zinc (mg l^{-1})	13.56
Copper (mg l^{-1})	4.865

Characteristics of the experimental field soil

The initial soil was neutral in reaction with pH of 7.1 and normal in EC (0.37 dS m^{-1}). The organic carbon content was 0.43 per cent. The available potassium (K) was found to be relatively higher in amounts (259 kg ha^{-1}) when compared to available nitrogen (N) and phosphorus (P) (120 kg ha^{-1} and 18 kg ha^{-1} respectively). The exchangeable calcium, magnesium, sodium and potassium content of the soil were 113.6, 32, 15.4 and 11.83 mg kg^{-1}, respectively. (Table 3). Soil physico-chemical charecteristics confirms the reports of Chandra *et al.*, 2004; Selvamurugan *et al.*, 2013)

Table 3. Characteristics of initial experimental soil

Parameters	Values
Soil series	Irugur
Sub group	Ustorthent
Mechanical composition	
Clay (per cent)	17.7
Silt (per cent)	19.7
Sand (per cent)	33.1
Bulk density (g cc^{-3})	1.17
Particle density (g cc^{-3})	1.21
Chemical composition	
Ph	7.1
EC(dSm^{-1})	0.37
Organic carbon (per cent)	0.43'
Available Nitrogen (kg ha^{-1})	120
Available Phosphorus (kg ha^{-1})	18
Available Potassium (kg ha^{-1})	259
Exchangeable Sodium (mg kg^{-1})	15.41
Exchangeable Calcium (mg kg^{-1})	113.66
Exchangeable Magnesium (mg kg^{-1})	32
Exchangeable Potassium (mg kg^{-1})	11.83

Impact of Biomethanated spentwash on soil charecteristics

The pH of the soil is slightly increased with increasing dose of spent wash application but there was no significant change is observed in pH of the soil. The highest pH recorded in T3 (30KL + NP + 50 % K as per recommended dose) at Initial stage of crop. The slight reduction in Ph was observed in the treatments T5, T6 and T7. This may be due to biocompost application along with spentwash (Table 4). The EC of the soil is slightly increased with increasing dose of spent wash but it was significantly higher than the control at all stages. The highest EC of the soil was recorded 0.56 dS m^{-1} in T_4 (20KL + NP + 50 % K as per recommended dose). The organic carbon content of the soil in all the treatments was significantly increased with increasing dose of spent wash. The initial organic carbon content was in the range of 0.41 to 0.48%. The increase in organic carbon was observed in T5, when compared to control (0.48 per cent) and there was significant increase in content of organic matter at every stages. (Table 4).

Selvalakshmi *et al.*, (2001) also indicated a reduc-

Table 4. Effect of biomethanated spentwash on Physico chemical charecteristics of soil

Treatments	pH			EC (dSm^{-1})			Organic carbon (%)		
	Aug	Jan	June	Aug	Jan	June	Aug	Jan	June
T1	7.10	7.54	7.54	0.37	0.43	0.50	0.43	0.45	0.47
T2	7.25	7.87	7.88	0.35	0.48	0.52	0.48	0.45	0.48
T3	7.33	7.85	7.85	0.32	0.50	0.53	0.45	0.47	0.49
T4	7.45	7.52	7.52	0.33	0.51	0.56	0.43	0.44	0.47
T5	7.68	7.59	7.42	0.34	0.45	0.48	0.48	0.58	0.62
T6	7.88	7.62	7.59	0.35	0.45	0.47	0.42	0.44	0.46
T7	8.07	7.69	7.61	0.35	0.45	0.47	0.41	0.44	0.46
Mean	7.53	7.66	7.63	0.34	0.40	0.50	0.44	0.47	0.49
SE	0.015	0.006	0.018	0.005	0.005	0.005	0.004	0.003	0.002
CD	0.05	0.02	0.12	0.017	0.02	0.008	0.01	0.01	0.01
CV	0.22	0.11	0.08	1.09	1.40	1.09	0.95	1.34	1.25

tion in soil pH due to application of spentwash. Basker *et al*., (2001) reported that application of distillery effluent significantly increased the pH and EC of the soil from the initial level and they stated the high salt load of effluent might have increased the soluble salt content of the post harvest soil. Jeyasubha *et al.* (2001) indicated that application of treated spentwash at different dilutions in sugarcane cultivated soil slightly increased the soil pH and EC. But the organic carbon content was decreased as the rate of dilution increased. Subash Chandra Bosh *et al.* (2002) observed a significant increase in the pH of the post harvest soil due to the application of graded doses of primary treated distillery effluent. However the increase was only by 0.2 units which fall within neutral reactions even at higher dose of distillery effluent (6.25 lakhs litre ha^{-1}).

Available Nitrogen, phosporous and Potassium content of soil

The increase in available N was observed in the spentwash applied field. The treatment T5 recorded maximum N and incresed to 203kg ha $^{-1}$ due to application of spentwash along with biocompost. Available P is also maximum in the treatment T5 and it act as a good source of plant nutrients and enhanced the growth and yield of sugarcane. Available K in the field is already high (260kg ha^{-1} and it was increased to 344kg ha^{-1}in the treatment T5. The rich source of available K in the spentwash may reason for maximum K in all the treatments. Available N and K status of soil was increased with the application of spent wash. The increased N and K availability in soil might be due to the additional N and K support from the spent wash and the other reason for the significant increase in the available N and K status of the soil might be due to the enhanced microbial activity due to significant addition of organic matter. As the spent wash contains sufficient N and K, it is considered as source of nutrient and applied for cultivation of crops (Table 5). Application of distillery spentwash to alkali soil significantly in-

Table 5. Effect of biomethanated spentwash on Macronutrients in kg ha^{-1}

Treatments	Available N			Available P			Available K		
	August	January	June	August	January	June	August	January	June
T1	120	149	152	18	21	23	259	273	280
T2	127	164	172	15	18	20	260	270	275
T3	122	165	173	17	20	22	245	268	273
T4	129	166	172	12	17	20	233	243	263
T5	153	196	203	18	23	30	260	299	344
T6	129	173	180	16	20	25	258	263	270
T7	124	183	185	17	20	25	259	265	270
Mean	129	177	183	16.1	17.6	25	253	269	282
SE	1.30	0.68	1.24	0.07	0.15	0.14	2.23	1.26	0.51
CD	4.55	2.39	4.31	0.08	0.39	0.51	7.82	4.43	4.27
CV	0.68	0.70	1.21	0.47	0.52	0.10	0.70	0.92	0.42

creased the available P content of the soil. The acidity of distillery spentwash had solubilized the native insoluble soil P and thus helped to increase the available P. The field experiments conducted by Bhat and Doddamani (1998) revealed that there was an increase in soil available N, P and K and uptake of these nutrients by sugarcane at 10 times dilution compared to 25 and 50 times dilution of spentwash.

Exchangable Calcium and Magnesium

The application of spentwash markedly increased the Exchangeable Ca content. The highest Exchangeable Ca concentration at initial stage of crop was 129.26 mg kg^{-1}. Increase in the rate of spentwash application significantly increased the Exchangeable Ca concentration. Exchangeable Mg concentration was found significantly increased due to the application of spentwash. The highest Mg concentration was 44.94 mg kg^{-1} at initial stage of crop growth. Increase in the rate of spentwash application significantly increased the Exchangeable Mg concentration.. A slight decrease in Ca and Mg concentration was observed in the biocompost applied treatments (T6 and T7). Chlorine content was ranged from 221 to 258 mg kg^{-1}, When compared to other treatments the increase in chloride content was maximum in the treatment T5 (221 to 340 mg kg^{-1}) (Table 6). The exchangeable Ca and Mg contents of the post harvest soil were significantly increased due to the application of graded doses of distillery effluent. This might be due to addition of Ca and Mg either through the effluent addition (Baskar *et al*., 2001 and Kayalvizhi *et al*., 2001). An increase in the availability of Ca and Mg from 1,400 mg $kg^{-1}$to 2,200 and 126 to 470 mg kg^{-1} respectively due to the application of 10 times diluted distillery effluent. The increase in the contents of these elements might be the reason for the little increase in the pH of post harvest soil upon effluent application.

The application of distillery spentwash to banana (poovan) increased the soil available Ca and Mg contents, which might be due to addition of Ca and Mg either through the effluent addition (Baskar *et al.,* 2001; Kayalvizhi *et al.,* 2001) or the solubilising effect of distillery effluent on the unavailable native forms.

Soundarrajan *et al*., (2007) reported that the raw spentwash significantly increased the soil organic matter and also the secondary nutrients like Ca and Mg. They reported that, the Exchangeable Sodium Percentage level was found to be high in the control than spentwash applied treatments such reduction was due to the free acidity of spentwash, organic acids and CO_2 produced during decomposition which solubilises the native alkaline earth carbonates and release soluble Ca. This Ca^{2+} thus brought in solution and Ca + Mg content of spentwash.

Baskar *et al.,* (2003). They suggested that the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre-plant application (40 to 60 days before planting) to give sufficient time for the natural oxidation of organic matter. Application of distillery spentwash significantly increased the EC, organic carbon, Ca, Mg, available N, P, K and micronutrient status of the soil. The untreated distillery spentwash was acidic (pH 3.5-4.0) and was suggested to be used effectively for the reclamation of non-saline sodic soil

Growth parameters and Yield

The plant height was 180cm in T1 and it is increased to 197cm in the treatment T5. The maximum cane

Table 6. Effect of biomethanated spentwash on Calcium,Magnesium and Chloride in mg kg^{-1}

	Calcium			Magnesium			Chlorides		
Treatments	August	January	June	August	January	June	August	January	June
T1	112.13	114.39	115.82	31.15	25.34	27.21	252.30	303.50	345.50
T2	122.87	121.70	115.87	25.79	35.19	28.73	233.40	320.80	360.20
T3	129.26	119.37	113.21	44.94	34.44	33.29	258.30	330.58	345.50
T4	121.10	120.86	111.66	36.72	33.12	28.05	216.60	345.50	360.60
T5	128.23	129.70	132.23	31.48	32.58	31.09	221.50	315.20	340.55
T6	125.62	118.75	113.42	38.34	33.15	29.83	244.40	320.50	360.45
T7	127.17	118.65	112.25	33.25	31.15	27.45	253.20	330.50	345.20
Mean	123.77	119.49	113.49	34.52	32.14	28.37	240.00	324.00	351.10
SE	0.29	0.14	0.09	0.31	0.17	0.14	0.14	0.17	0.23
CD	1.05	0.49	0.31	1.09	0.58	0.51	0.49	0.58	0.80
CV	0.29	0.14	0.09	1.11	0.63	0.10	0.52	0.63	0.86

thickness, internode length and internodes per plant was observed in the treatment T5, when compared to other treatments. Application of 40KL + Biocompost (1.0 tonnes) (T_5) recorded higher yield of 76 t ha^{-1}, + NPK as per recommended dose (T1) recorded the lower yield of 53 t ha^{-1} (Table 7) . The increase in growth parameters and cane yield may be due to increase in microbial activity in the soil (Rajkishore and Vignesh, 2012) that ultimaely increased the nutrient availability to plants. The increase in sugarcane growth parameters using 10% spentwash generated from Matiari Sugar Mills, Pakista was observed by Kaloi *et al.* (2015). The spentwash collected from Eid Parry distillery, district Cuddalore, India, which had more or less similar characteristics and obtained a cane yield of 115 t ha^{-1} with a 47.43% increase at 10% spentwash over control (Sivaloganathan *et al.,* 2013). On the other hand, Armengol *et al.* (2003) obtained 64% increase in cane yield at 20% concentration due to its low salt content (EC = 1.98 dS m^{-1}).

Conclusion

From the results of field experiments on Sugarcane, it is concluded that the treatment T5 with biocompost (1tha^{-1}) application and spentwash 40KL proved in increasing the crop yield, yield attributes and the plant nutrient contents as well as the soil available nutrient status. Increase in the rate of spentwash application markedly increased the Exchangeable Ca, Mg, Na, K concentration and relatively higher values were observed in soil that received 40kl spentwash with 1 tonnes of biocompost. Mineralization of organic matter and the nutrients present in the effluent are responsible for the increase in the availability of nutrients in soil.

Thus substituting spentwash as a fertilizer will solve the problem of waste disposal and also minimize the usage of inorganic fertilizer and improve the plant growth and yield without affecting the soil health. In the present investigation, it is concluded that the PMDSW could very well be used as a source of plant nutrients for sustaining the crop yields, soil productivity and health without polluting the soil. Further, K fertilizer could be completely skipped off with distillery spentwash application, which not only saved the K fertilizer input but also considerably cut short the fertilizer import bills.

References

APHA. 1998. Standard Methods for the Examination of Water and Wastewater. 20 th ed., Washington DC, American Public Health Association.USA: 83

Armengol, J. E., Lorenzo, R. and Noemi, F. 2003. Use of vinasse dilution in water as an alternative for improving chemical properties of sugarcane planted vertisols. *Journal of Cultivos Tropicales.* 24(3): 73–76.

Baskar, M., Kayalvizhi, C. and Subash Chandra Bose, M. 2003. Eco-friendly utilization of distillery effluent in agriculture-A review. *Agricultural Review.* 24(1): 16-23.

Baskar, M., H. Gopal, C. Kayalvizhi, M. Sheik Dawood, M. Subash Chandra Bose, M. and Rajukkannu, K. 2001. Influence of pre-plant application of distillery effluent and fertilizers on soil properties and yield of sugarcane. **In:** *National seminar on Use of poor quality water and sugar industrial effluents in agriculture*, ADAC & RI, TNAU, Tiruchirapalli, Feb. 5, 76-82.

Bhat, S. N. and Doddamani, V.S. 1998. Impact of distillery effluent on availability of nutrients, nutrients uptake and quality of sugarcane. **In:** *Proc. National Seminar on Application of treated effluent for irrigation*, held at REC, Tiruchirappalli, Mar. 23, 7.

Chandra, R., Kumar, P. and Singh, J. 2004. Impact of an aerobically treated and untreated (raw) distillery effluent irrigation on soil micro flora, growth, total chlorophyll and protein contents of *Phaseolus aures*

Table 7. Growth parameters and Yield of Sugarcane

S. No.	Treatment	Plant height (cm)	Cane thickness (mm)	Internode length (cm)	Internode (Plant^{-1})	Yield (t ha^{-1})
1	T1	180	23	10	20	53
2	T2	185	23	11	21	55
3	T3	187	24	12	20	60
4	T4	188	24	11	23	65
5	T5	197	28	13	25	76
6	T6	187	25	11	23	73
7	T7	183	23	10	24	78

Values are mean of three replication

L. *Journal of Environmental Biology.* 25(4) : 381-385.

Chandraju, S., Siddappa and Chidankumar, C. S. 2013. Studies on the impact of irrigation of distillery spentwash on the yield of cotton (*Gossipium hirsutum*) and groundnut (*Arachis hypogaea*) oil seed plants. *Nature Environment and Pollution Technology*, 12(1) : 143-146.

Chopra, A. K., Srivastava, S., Kumar, V. and Pathak, C. 2013. Agro-potentiality of distillery effluent on soil and agronomical characteristics of *Abelmoschus esculentus* L. (okra). *Environmental Monitoring and Assessment.* 185 : 6635–6644.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India. Pvt. Ltd., New Delhi. 275.

Jeyasubha, S, J. Balamurugan, K. and Rajukkannu, A.R. 2001. Haroon and M. Subash Chandra Bose. Fertigation of sugarcane with primary treated distillery effluent. **In:** *National Seminar on Use of poor quality water and sugar industrial effluents in agriculture*,ADAC & RI, TNAU, Tiruchirapalli, Feb 5,79.

Joshi, H. C. 2001. Bio-energy potential of distillery effluents. URL: http://www.undp.org. in/Programme/ GEF/june/10 - 15. htm.

Kaloi, G. M, Memon, M, Memon, K. S. and Tunio, S. 2015. Integrated use of spentwash and mineral fertilizers on germination and initial growth of sugarcane (*Saccharum officinarum* L.) *Soil and Environment.* 34(1): 01–08.

Kanimozhi, R. and Vasudevan, N. 2010. An overview of wastewater treatment in distillery industry. *International Journal of Environmental Engineering*. 2: 159-184.

Kayalvizhi, C, H. Gopal, M. Baskar, M. Sheik Dawood, Subash Chandra Bose, M. and Rajukkannu, K. 2001. Effect of fertigation with distillery effluent on soil properties and yield of sugarcane. **In:** *National seminar on Use of poor quality water and sugar industrial effluents in agriculture*,ADAC & RI, TNAU, Tiruchirapalli, Feb.5, 84.

Mohan Naidu. 2002. Global spentwash management technologies their incorporation and Tamil Nadu distilleries. **In:** Proc. of the National Conference, SISMA, Tamil Nadu, 92-97.

Mohamed Haroon, A. and Subash Chandra Bose, M. 2004. Use of distillery spentwash for alkali soil reclamation, treated distillery effluent for fertigation of crops. *Indian Farmers*. 53 (11) : 48-51.

Pugazh, G., Thiyagu, R. and Sivarajan, P. 2016. Physicochemical characterization of raw and diluted effluent from distillery industry. *International Research Journal of Engineering and Technology.* 3**(**4): 2055–2059.

Rajagopal, V., Paramjit, S. M., Suresh, K. P., Yogeswar, S., Nageshwar, R. D. V. K. and Avinash, N. 2014. Significance of vinasses waste management in agriculture and environmental quality—review. *African Journal of Agricultural Research.* doi:10.5897/ ajar2014.8819.

Rajkishore, S. K, and Vignesh, N. S. 2012. Distillery spentwash in the context of crop production: a review. *International Quarterly Journal of Life Sciences.* 7(3) : 369–375.

Selvamurugan, M., Ramkuar, V.R. Doraisamy and Maheswari. M. 2013. Effect of biomethanated distillery spentwash and biocompost application on soil quality and crop productivity. *Asian Journal of Science and Technology***,** 10,124 - 129

Sivaloganathan, P., Murugaiyan, B., Appavou, S. and Dharmaraj, L. 2013. Effect of dilution of treated distillery effluent (TDE) on soil properties and yield of sugarcane. American *Journal of Plant Sciences*. 4 : 1811–1814.Agricultural Research. doi:10.5897/ ajar2014.8819.

Selvalakshmi, M., J. Balamurugan, K. Rajukkannu, S. Pazhanivelan and M. Subash Chandra Bose. 2001. Fertigation of rice with primary treated distillery effluent. **In:** Proc. Nat. Sem. on *Use of poor quality water and sugar industrial effluents in agriculture,* ADAC & RI, Tiruchirapalli, Feb. **5,** 81

Soundarajan, M., Anandakrishnan, B. Sheik Dawood, M. Bhaskar, M. and Murugesan, R. 2007. Studies on pre plant application of distillery effluent to sugarcane on different soil type. **In:** Abstracts of *National Conference on Ecofriendly Utilization of recyclable organic resources from the sugar and Distillery Industries for Sustainable Agricultur*e. held at ADAC & RI,Tiruchirappalli-9, TNAU., during March 6 - 7th, 47.

Subash Chandra Bose, M., Gopal, H., Baskar, M., Kayalvizhi, C. and Sivanandham, M. 2002. Utilization of distillery effluent in costal sandy soil to improve soil fertility and yield of sugarcane. **In:** *Symposium No.* 30, 17th WCSS, Aug. 14-21, Thailand, 1980-1988.

Subbiah, B.V. and Asija, C.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science*. 25 : 259-260.

Walkley, A. and Black, C.A. 1934. An estimation of methods for determining organic carbon and nitrogen in soils. *Journal of Agricultural Science*. 25: 598-609.