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An Overview on Application of Sugar Industry Waste by-Products on Soil Properties and Crop Yield

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ABSTRACT

Pressmud and molasses are important by-products of sugar industry where in molasses is the chief source for the production of alcohol in distilleries by fermentation method and by-product produced is known as spent wash. It is one of the most trouble some, complex and strongest organic industrial effluents, having extremely high COD and BOD values. Preventing the generation of sugar industry wastes, reducing the volume or toxicity of hazardous wastes by water recycling and reuse to reduce the pollution. The land application of distillery spent wash and pressmud often benefits water pollution control and utilization for agricultural production. Hence, controlled application of spent wash to the land as irrigation water helps in restoring and maintaining soil fertility, improving physical properties, increasing water retention capacity and enchancing soil microflora. Experiment was conducted in farmers' fields grown with various crops like, finger millet, maize, groundnut, etc., from 2006 to 2019 by University of Agricultural Sciences, Bangalore, where distillery spent wash was applied one time in rainfed areas. The soil properties were increased as compared to the initial soil samples. Later, sugar industry solid wastes, enriched solid wastes and compost prepared using pressmud were applied to fields, where soil properties and yield were found to be increased. The yield was also found to be more profitable than usage of farm yard manure as nutrient source.

Keywords: Spent wash, Pressmud compost, Distillery effluent, Agro industry waste

SUGARCANE factories in India, produces sugar and by-products like bagasse, molasses and pressmud, etc. Distilleries become integral part of sugar factory where the by-product of sugar factory is used as main ingredient for alcohol production. A solid waste by-product of sugar industry is pressmud and 18000 tonnes of pressmud is produced annually. In India there are more than 295 distilleries producing 2.7 billion litres of alcohol generating 40 billion litres of waste water and 1100 million cubic meters of biogas.

The world's total production of alcohol from cane molasses is more than 13 million m^3 per annum. A dark brown highly organic aqueous distillery effluent stream is also produced known as spent wash and is approximately 12-15 times by volume of the product alcohol. Since India cultivates sugarcane extensively throughout the year, molasses from sugar industry is used largely in ethanol production due to its easy availability and low cost.

Molasses contain mostly dark brown coloured recalcitrant compounds collectively termed as melanoidin polymers which are the product of maillard reaction between the amino acids and carbonyl groups present in molasses. With their high biochemical oxygen demand, these effluents are termed as "spent wash" which causes environmental hazard when released in water bodies, they cause oxygen depletion and associated problems and if released directly into soil they reduce the soil alkalinity and manganese availability. Besides causing anaesthetic discolouration of water and soil, melanoidin pigments are also toxic to microorganisms present in soil and water. Dark brown colour of the effluent is highly resistant to microbial degradation and other biological treatment. Melanoidins have recalcitrant compounds; thus the conventional treatment methods are not effective for complete colour removal from this stream and colour can even be increased during anaerobic treatments, due to re-polymerization of compounds. Anaerobic digestion of effluents produces dark brown sludge which is used as fertilizer and the coloured water is discharged after diluting them several folds with water.

Thus, ultimately fresh water resource which is a precious commodity in most parts of the world is wasted. The effluent is highly coloured with an extremely high chemical oxygen demand (COD) load and contains high percentage of dissolved organic and inorganic matter. Apart from high organic content, distillery waste water also contains nutrients like nitrogen, phosphorus and potassium that can lead to eutrophication of water bodies.

Effluent disposal even after conventional treatment is hazardous and has a high pollution potential due to the accumulation of non-biodegradable recalcitrant compounds, which are mostly coloured and in a highly complex state melanoidin have anti-oxidant properties causing toxicity to many microorganisms involved in wastewater treatment processes. Lowering of pH value of the streams, increasing organic load and obnoxious smell are some of the major problems due to distillery waste water. Spent wash when subjected to bio-methanation loses upto 85 per cent of its BOD and becomes distillery effluent (treated spent wash). However spent wash cannot be directly applied to the growing crops because of its high BOD and COD. So it should be applied before the planting of crop or diluted with water and then applied to growing crops.

METHODOLOGY

University of Agricultural Sciences, Bangalore collaborating with sugar industries conducted experiments in which they applied different volumes per hectare of spent wash to different crops. The initial, at growth stage and after harvest soil samples were collected and analysed from 2006 to 2019. Experiments were also conducted to know the effect of different sugar industry effluents and solid wastes on soil properties, yield of crops like maize, groundnut, horsegram and finger millet. Pressmud compost was enriched with phosphorus to see its effect on yield and soil properties using different treatment combinations. The yield data and soil properties were subjected to analysis and findings are reported in the study.

Based on results of the research conducted on various crops by several researchers from University of Agricultural Sciences, Bangalore, the dosage for each crop was fixed with respect to one time application of spentwash and advocated to farmers across Karnataka. Further researchers also tried with various doses of bi-product of sugar industry like treated effluent, pressmud, compost prepared from pressmud and composts enriched with nutrients to know their effect on soil properties and yield of crops like fingermillet, maize, horsegram, etc.

The paper discusses on the characteristics of spentwash, pressmud and pressmud compost and their effect on the soil properties and yield of the crops. The results of the experiments conducted at different fields to find out the possibility of utilising the distillery effluent an efficient way are discussed in this paper.

Generation of Spent Wash

Molasses which is used as raw material for production of alcohol in distilleries contains 7-8 per cent glucose, which is converted in to alcohol by fermentation process. Fermentation is carried out by adding yeast and necessary nutrients to dilute molasses. Fermentation period is about 24 to 30 hours and about 7.5 per cent to 9.5 per cent alcohol is formed in the fermented molasses. After completion of fermentation, distillation of fermented wash is done to recover aqueous alcohol as distillate. Eight to twelve litres of spentwash are generated for every litre of alcohol. The spent wash contains organic matter and nutrient minerals derived from the sugarcane. The spent wash is anaerobically treated in the digester. During this anaerobic degradation, the organic matter is converted into biogas (55 % methane) which brings down the BOD value to 6,000-7,000 ppm from the original level of about 45,000 ppm. The evolved bio-gas is to be used as fuel in the boiler. The treated bio-methanated spent wash is subjected to reverse osmosis membrane

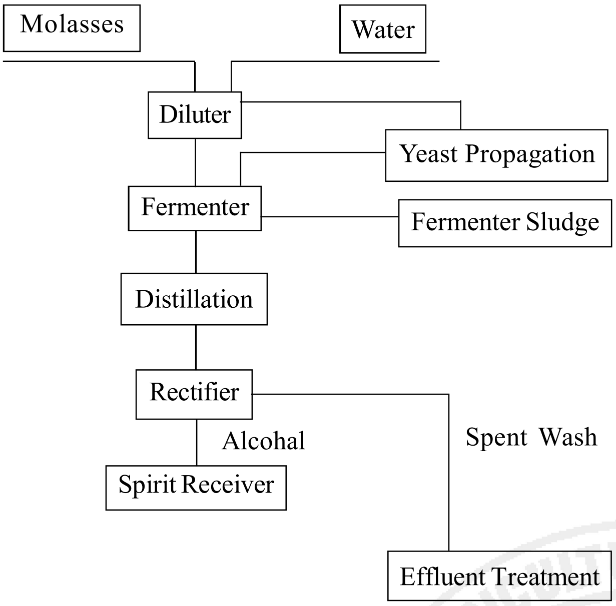

Fig. 1: Flow chart of spentwash generation

filtration to concentrate the spent wash and separate the usable permeate water (desalinized water).

Characteristics of Spent Wash

Spent wash is a sugarcane based distillery effluent which is dark brown highly organic in nature, one of the most complex and strongest organic effluent and it is characterized by high BOD and COD values. Sindhu *et al.* (2007) mentioned that spent wash being plant origin, it contains considerable amount of plant nutrients and organic matter. Spent wash is acidic effluent rich in organic carbon, potassium and sulphur, considerable amount of nitrogen, phosphorus, traces of micronutrients. Hence it could be used as a form of nutrient supplement for crop production. Rajukkannu and Manickam (1996) indicated that since spent wash is highly acidic in nature (pH ranges from 3.8 to 4.0) and contains fairly good amount of calcium and magnesium, this could be utilised as an organic amendment for the reclamation of sodic soils. However, it is non- toxic, bio-degradable, purely of plant origin and contains large quantity of soluble organic matter and plant nutrients (Alam *et al.*, 2008). Reaction of the spent wash collected from distilleries was neutral. Nitrogen, phosphorus and potassium were 0.10, 0.02 and 1.01 per cent, respectively (Table 1).

TABLE 1

Physico-chemical characteristics of distillery spentwash

Parameters	Values
pH	6.99
EC (dS m^{-1})	26.4
Total Nitogen (%)	0.10
Total Phosphorus (%)	0.02
Total potassium (%)	1.01
Sodium (mg L^{-1})	601
Calcium (mg L^{-1})	1326
Magnesium (mg L^{-1})	734
Total dissolved solids (%)	6.10
Chloride (mg L^{-1})	4012
Sulphur (mg L^{-1})	498
Iron (mg L^{-1})	27.1
Zinc (mg L^{-1})	5.32
Copper (mg L^{-1})	2.12
Manganese (mg L^{-1})	3.21

(Source: Distillery report 2019)

Application of Spent Wash

Spent wash was applied to land at least one month before monsoon, land was ploughed and then sowing of seeds or transplanting of crops was taken. Quantity of application of spent wash depends on nitrogen requirement of crop. Recommended quantity for spent wash for major crops in red and black soil areas and rainfed and irrigated areas of Karnataka are given in Table 2 and 3, respectively.

Utilization of Distillery Spent Wash in Agriculture/Crop Production:

Application of spent wash as a source of irrigation found to influence the soil properties and yield of agricultural crops. Use of spent wash as fertilizer and soil amendment has become popular in agriculture. Spent wash is rich in organic matter, on application creates organic fertilization in soil which raises the pH of the soil, increase availability of certain nutrients

TABLE 2
Recommended quantity of spentwash for major crops in red and black soil areas of Karnataka

Crop	Red soils		Black soils	
	Quantity of spentwash (000 Litre ha^{-1})	Quantity of Super Phosphate (kg ha^{-1})	Quantity of spentwash (000 Litre ha^{-1})	Quantity of Super Phosphate (kg ha^{-1})
		Cereals		
Maize	100	187	100	187
Jowar	65	169	65	169
Finger millet	50	187	50	187
		Pulses		
Red gram	25	281	25	281
Soybean	25	344	25	344
		Oil seeds		
Groundnut	25	281	25	281
Sunflower	37.5	266	35	269

Source: package of practices by SAU's, Karnataka (Chapter7, pp: 46-48)

TABLE 3
Recommended quantity of spentwash for major crops in Irrigated and Rainfed areas of Karnataka

Crop	Recommended dose of fertilizer		Amount of spentwash (000 Litre/ha)	
	Irrigated	Rainfed	Irrigated	Rainfed
		Cereals		
Wheat	100:75:50	50:25:00	100	50
Maize	150:75:37.5	100:50:25	150	100
		Vegetables		
Chilli	150:75:75	100:50:50	150	100
Okra	125:75:625	-	125	-
Cauliflower	150:100:125	-	150	-
Tomato	115:100:60	60:50:30	115	60
		Commercial crops		
Sugarcane	250:75:190	-	250	-

(Source: UASB Package of Practice, 2015)

(Kamble *et al.,* 2017). One cubic meter of methanated effluent contains nearly 5 kg of potassium, 300 grams of nitrogen and 20 gram phosphorus. The distillery effluent contains 0.6 to 21.5 per cent potash as K_2O, 0.1 to 1.0 per cent phosphorus as P_2O_5 and 0.01 to 1.5 per cent nitrogen (Rath *et al.,* 2011).

Effect of Spent Wash Application Agricultural on Crop Yields

Maize

At University of Agricultural Sciences Bangalore, GKVK field monitoring studies of one time application of spent wash was conducted in collaboration with distilleries situated at Southern Districts of Karnataka state from 2006 to 2019. Monitoring studies showed that increase in average maize yield by 25-43 per cent during 2006, 44 per cent during 2007, 24.63 per cent during 2008, 27.06 per cent during 2009, 28.98 per cent during 2010, 30.64 per cent during 2011, 25.48 per cent during 2012, 25.68 per cent during 2013, 28.73 during 2014, 35 per cent during 2015, 34.92 per cent during 2016, 33.43 per cent during 2017, 21.78 per cent during 2018 and 22.75 per cent during 2019 with one time controlled land application of spentwash (100 KL $ha^{-1}$of spentwash along with recommended dose of fertilizer).

Similar results were also found by Chhonkar *et al.* (2000) who reported that increase in maize yield with continuous application of post methanated effluent upto three years along with recommended dose of fertilizer. He carried out field experiment for maize crop for three subsequent years with 10 per cent, 20 per cent, 30 per cent and 40 per cent post methanated effluent application along with 100 per cent recommended dose of fertilizer. Study showed that yield of maize was increased by 8.27 per cent, 16.88 per cent and 45.59 per cent after 10 per cent post methanated effluent application during first, second and third year respectively. Similarly 10 per cent, 50.64 per cent and 70 per cent yield increase after 20 per cent post methanated effluent application, 6.8 per cent, 41.55 per cent and 48.27 per cent yield increase after 30 per cent post methanated effluent and 9.65 per cent, 5.19 per cent and 42.14 per cent yield increase after 40 per cent post methanated effluent application during first, second and third year respectively. The per cent increase in yield over control was found to be 16 per cent. Yield obtained was 74.7 q ha^{-1} in 1:10 dilution and in control 64.4 qha^{-1} with 6 irrigations.

Suganya and Rajannan, (2009) found that, yield of maize significantly increased by application of distillery spentwash at the rate of 100 KL ha^{-1} along with recommended dose of nitrogen and phosphorus and also yield increased with application of 75 per cent recommended dose of nitrogen and phosphorus along with 100 KL ha^{-1}. Basal application of post methanated distillery spent wash at the rate of 80 KL $acre^{-1}$ in maize found to increase 1.61 times compared to control as per the results reported by Nandakumar (2009). Similar results were revealed by Sridharan, (2007) who found that grain yield was increased by the application of post methanated distillery spent wash.

Finger Millet

Monitoring studies showed that increase in average finger millet yield by 25-30 per cent during 2006, 29.03 per cent during 2007, 26.99 per cent during 2008, 23.52 per cent during 2009, 30 per cent during 2010, 33.3 percent during 2011, 29.02 per cent during 2012, 17.8 per cent during 2013, 29.41 per cent during 2014, 35.95 per cent during 2015, 36.86 per cent during 2016, 32.23 per cent during 2017, 21.54 and 20.00 per cent during 2018 and per cent during 2019 (50 KL ha^{-1} of spentwash application along with recommended dose of fertilizer).

Studies conducted by Sathish *et al.,* (2016), with application of spentwash at 50 m^3 ha^{-1} before sowing of the crops. The results showed that yield of dryland crop like finger millet increased to an extent of 10-25 per cent with one time application of spent wash to dry lands compared to farmers practice.

Groundnut

The study on one time application of spent wash to dry lands for groundnut crop were carried out during the year 2007 to 2016 by University of Agricultural Sciences, Bangalore. The study revealed that application of 150 KL ha^{-1} of spent wash along with recommended dose of fertilizer application increased the yield by 28 per cent during 2007, 7.38 per cent during 2008, 25 per cent during 2009, and 26.14 per cent during 2010, 33.33 per cent during 2012 and 33 per cent during 2016.

Devarajan *et al.* (1998) conducted studies on different ratios of spent wash and water dilution and found that yield of groundnut is significantly increased by 22.31 per cent at 1:50 dilution ratio along with recommended dose of fertilizer compared to control. Darmalingiah, (2011), studied the effect of distillery spent wash on yield of groundnut with 0.25, 0.5, 0.75, 1.00 and 1.5 times of recommended dose of nitrogen application through spent wash and fertigation. The study showed that 1.5 times of recommended dose of nitrogen application through spent wash produced the highest pod yield of 3100 kg ha^{-1}.

Horsegram

The study on one time application of spent wash to dry lands for horse gram crop were carried out during the year 2007, 2008, 2013 to 2017. Monitoring studies showed that increase in average horse gram yield by 31.54 per cent during 2007, 23.66 per cent during 2008, 38.6 per cent during 2013, 13.87 percent during 2014, 11.63 per cent during 2015, 11.24 per cent during 2016, 10.71 per cent during 2017 spent wash (25 KL $ha^{-1}$of spent wash along with recommended dose of fertilizer).

Effect of Application of Spent Wash on Soil Chemical Properties

In order to study the effect of spent wash on soil chemical properties field monitoring studies of one time application of spent wash (2006 to 2019) was conducted in southern Karnataka. The fields were selected in Mandya district. The surface soil samples were collected from 242 number farmer's fields where maize, fingermillet groundnut and horsegram were grown and analyzed for variation in pH, EC, available potassium and exchangeable sodium at different stages due to the application of spent wash. All these fields were applied with recommended dose of nutrients and distillery spent wash at the rate of 100 m^3 ha^{-1}.

The soil samples collected were found to be acidic to near neutral in reaction (pH of 4.42-7.97). The EC values indicated that the soils are normal (0.02 d Sm^{-1}-0.634 dSm^{-1}), with respect to salt content, the available potassium content of the soil showed low to high (106 kg ha^{-1}-498 kg ha^{-1}). However, the exchangeable sodium content of the soil varied between 0.05 C mol (P^+) kg^{-1} to 1.41 C mol (P^+) kg^{-1}.

The soil samples collected during crop growth stage were found to be slightly acidic to alkaline (5.1-8.27) in reaction and with respect to salt content of soil, the EC values increased slightly but within the permissible limits and were ranged from 0.028 dSm^{-1} to 1.60 d Sm^{-1}. The available potassium content of the soil increased significantly and it ranged from 169 kg ha^{-1} to 2988 kg ha^{-1}. Exchangeable sodium content of the soil increased compared to initial and varied between 0.15 C mol (P^+) kg^{-1} - 2.01 C mol (P^+) kg^{-1} of soil. The results from the report 2006-2017 indicated that after 60 days of spent wash application to soil, there was slight increase in the salt content, exchangeable sodium and available potassium content of soils due to the addition of nutrients through spent wash as compared to initial samples which were low in nutrients content due to nutrients removal by previous crop.

Increase in pH might be due to organic matter decomposition brought by microbial oxidation (Mattiazo and Ada Gloria, 1985) and increase in EC due to high salt load of effluent, however the increase in the EC of the soil was well within the safe limit of 1.0 dSm^{-1}. Similar result was reported by Subhash Chandra Bose *et al*, (2002). Application of spent wash tremendously increased the potassium status of the soil which might be due to higher potassium content of the effluent (Subhash Chandra Bose *et al*, 2002).

At harvest of the crop, the pH values of all the soil samples showed slightly acidic to neutral reaction, electrical conductivity of soils decreased appreciably and the values ranged from 0.027 dSm^{-1} to 0.0797 dSm^{-1}. The available potassium content of the soil has decreased appreciably (118.69 kg ha^{-1}-2160 kg ha^{-1}). The exchangeable sodium content of the soil also has decreased and ranged between 0.08 C mol (P^+) kg^{-1} to 1.71 C mol (P^+) kg^{-1}. This might be due to removal of nutrients added through spent wash by the crops suggesting that application of distillery-spent wash once in 2 to 3 years may not cause any adverse effects on soils.

Baskar *et al*. (2001) revealed that pre-plant application of graded dose 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. Selvamurugan *et al.* (2013) showed that the pH and EC of the soil were substantially increased due to biomethanated distillery spent wash at various stages. There was a build-up of salt content with the application of biomethanated distillery spent wash. Nutrients content of the soil were tremendously improved by the addition of 35 m^3 ha^{-1} of biomethanated distillery spent wash. Latha *et al.* (2012) reported that application of graded dose of biomethanated distillery spent wash 100 KL ha^{-1}, along with recommended dose of nitrogen, phosphorus and potassium increases pH (7.31, 7.28 and 7.22 at 30, 60 and 90 DAS, respectively) and lowest was recorded in recommended dose of fertilizers (6.78, 6.72 and 6.62 at 30, 60 and 90 DAS) and EC was also found to be increased in treatment received 100KL ha^{-1} biomethanated distillery spent wash along with recommended dose of nitrogen, phosphorus and potassium (0.55, 0.49 and 0.39 dSm^{-1} at 30, 60 and 90 DAS, respectively) and lowest was recorded in recommended dose of fertilizers (0.35, 0.29 and 0.26 dSm^{-1} at 30, 60 and 90 DAS, respectively).

Application of digested effluent increased soil concentration of most elements particularly potassium and sodium as reported by Sweeney and Graetz (1991). Application of graded dose of distillery spent wash significantly increased the sodium content in spent wash treated soil (Kayalvizi *et al*. 2001). Application of distillery effluent at the rate of 1.25, 2.5, 3.75, 5.0 and 6.25 lakh litre ha^{-1} found to have high potassium content over control with an increase of 10, 25, 43, 58 and 70 kg ha^{-1} was recorded (Subhash Chandra Bose *et al*. 2002). The field experiment conducted by Joshi *et al*. (1996) revealed that at surface layer the available potassium content of soil substantially increased from 87 mg kg^{-1} (control) to 1075 mg kg^{-1} due to one-time controlled application of distillery effluent at 240 m^3 ha^{-1}. The application of bio-methanated spent wash to soil had shown a considerable increase in potassium from 432.52 to 470.44 kg ha^{-1} (Math *et al.,* 2011). Kuligod *et al.* (2013) reported that available potassium was found to be high in treatment received 1.5 times of nitrogen through spent wash (90,000 L ha^{-1} + balanced phosphorus through SSP) 2.51 C mol (P^+) kg^{-1} in surface layer and low in farmer practicing fertilizer application dose of 41:46:0 kg ha^{-1}.

Improved Utilization of Spent Wash

Spent wash can also be utilized for compost preparation with pressmud along with microbial culture. Composting is the decomposition of organic matter by a mixed population of microorganisms in a moist, aerobic environment. The composting process involves an interaction between the organic waste, microorganisms, moisture and oxygen. Composting of spentwash is carried out usually using pressmud generated from sugar mills. This biological process is activated optimizing the different parameters and composting is facilitated using microbial cultures.

Compost Technology and Factors Affecting Composting Technology

Compost technology is one of the most versatile and remunerative techniques for handling biodegradable solid wastes and emerges as the most widely applicable process for handling diverse wastes through recycling (Haug 1980; Sharma *et al.* 1997; Masato *et al.* 2005). Composting is particularly effective in converting wet materials, such as the spent wash, pressmud and other organic solid wastes produced from the sugar-distillery industries (Nandy *et al.* 2002; Strong *et al.* 2008), to a value added usable product that is readily disposed and has high agricultural use. The organic matter gets stabilized through decomposition and the pathogenic organisms are destroyed, the exothermic heat generated during the reactions dry the wet substrate (Ranalli *et al.* 2001). All of these advantages of waste stabilization are obtained with minimal outside energy input, the major energy resource being the organic wastes as substrates. There are several factors, affecting composting which includes include pH, moisture, temperature, C:N ratio, nature of substrate and aeration. Considering these fundamentals in view, composting of the spentwash has been a well established process and practice in India (Table 4).

TABLE 4
Factors responsible for composting

Factors	Optimum condition for good composting	References
pH	Optimum level for composting are between 6.0 to 8.0 and between 4.0 to 7.0 for the end product	Verdonck, 1988
Moisture	Optimum moisture condition is essential for the microbial degradation of organic wastes. Aerobic decomposition can proceed at moisture content between 30 and 100 per cent if aeration can be provided. Initially the moisture content may be between 45 and 75 per cent with 50 to 65 per cent as optimum.	Saranraj and stella, 2014
Temprature	Optimum level for composting is 50-70°C. The organisms do not carry decomposition for extended period at temperature above 70°C.	Haug 1980, 1993; Sowmeyan and Swamynathan G. 2008.
C : N Ratio	Under high carbon, the organisms die when the nitrogen is used up and decomposition decreases. Further, decomposition takes place when other organisms utilize the nitrogen stored in the dead organisms requiring more time to complete composting and optimum ratio for composting was 30:40.	Haug 1980, 1993; Sowmeyan *et al.* 2008
Nature of Substrate	The waste which contain high amount of organic matter, domestic waste, sewage, sludge and agricultural biomass.	Moorthy and Rao, 1998
Aeration	Aeration is necessary thermophilic aerobic composting to obtain rapid decomposition. Turning the material is the most common method of aeration. Optimum oxygen level required was 10 -15 per cent	Haug 1980, 1993; Sowmeyan *et al.* 2008

Production of Pressmud Compost using Sugar Mill Pressmud and Distillery Spent Wash

Composting of spent wash is carried out usually using pressmud generated from sugar mills. This biological process is activated optimizing the different parameters and composting is facilitated using microbial cultures (Nandy *et al.,* 2002; Sarangi *et al.,* 2005; Strong *et al.,* 2008). Pressmud compost is one of the value added products where pressmud from sugar industry is composted using spent wash generated in the distilleries. The process involves both aerobic and anaerobic digestion of agro-wastes. During the process, high molecular weight insoluble and not easily digestible materials are broken down by microbial action, resulting in both mineralized fraction of nutrients and stable organic matter (KBDA report, 2006). The process of pressmud composting utilizes the tremendous potential of spent wash for the benefit of both the distillery industry and the agricultural sector (Gaur 1979, 1985). Pressmud-compost serves as an economical and ecologically viable option not only to overcome pollution problems associated with spent wash but also to generate a valuable product for increasing crop productivity. Thus, the composting process is governed by the characteristics of pressmud, spent wash and micro-organisms. The characteristics of pressmud compost are depicted in Table 5.

Pressmud

Pressmud is a soft, spongy, amorphous and dark brown to brownish white material, containing sugar, fiber, coagulated colloids including can-wax, aluminous inorganic salts and soil particles (Satisha *et al.* 2005). Its composition and properties vary, depending on the quality of cane crushed and the process being used for clarification. The pressmud generated from the

TABLE 5

Physico-chemical characteristics of pressmud compost produced from activated composting of pressmud with distillery spentwash

Parameters	Value/concentration
pH	7.28
EC (dS/m)	3.02
Organic carbon (%)	49.09
Total Nitrogen (%)	2.21
Total Phosphorus (%)	1.22
Total Potassium (%)	1.84
Total Calcium (%)	0.86
Total Magnesium (%)	0.26
Sulphur (mg kg^{-1})	34.04
Sodium (%)	0.28
Iron (mg kg^{-1})	1238.00
Manganese (mg kg^{-1})	482.8
Zinc (mg kg^{-1})	141.20
Copper (mg kg^{-1})	72.30
Ni (mg kg^{-1})	0.19

(Source: Lavanya, 2019)

TABLE 6

Composition of typical pressmud from sugar factory

Parameters	Values
Bulk density (Mg m^{-3})	1.08
Maximum water holding capacity (%)	60.21
pH (1:10)	6.50
Electrical conductivity (dS m^{-1}) (1:10)	2.90
Organic carbon (per cent)	35.08
Total nitrogen (per cent)	1.80
Total phosphorus (per cent)	1.02
Total potassium (per cent)	1.28
Total calcium (per cent)	1.02
Total magnesium (per cent)	0.32
Total sodium (per cent)	0.03
Total sulphur (mg kg^{-1})	30.00
Total iron (mg kg^{-1})	1202
Total copper (mg kg^{-1})	77.40
Total manganese (mg kg^{-1})	253.20
Total zinc (mg kg^{-1})	119.40

(Source: Suma, 2018)

sugar industry contains a variety of essential elements with carbon to nitrogen ratio 16:36 suitable for composting. It is estimated that on an average each ton of pressmud contains about 10- 15 kg N, 36 kg P, 14 kg K, and 23 kg S (Tandon, 1992). The average composition of typical pressmud is given in Table 6.

Advantages of Pressmud-Composting with Pressmud and Spent Wash

Pressmud composting helps in recycle and reuse of pressmud and spent wash. Pressmud is used as a source of plant nutrient, an ameliorant for acidic and saline-sodic soils. It is a medium for germination and growth of seedlings and act as a carrier for microbial inoculants and applied as such to fields for raising crops (Deodhar 1991; Rajukkannu *et al.* 1996). It is however potential source of plant nutrients, which could be recycled to a valuable product through composting with pressmud and other substrates and provide organic manure to the nearby farmers in rural areas at lower cost.

Utilization of Pressmud Compost in Crop Production

Pressmud-compost produced by the distilleries were used for trials and the quantity applied was based on P requirement of Finger millet and sunflower. On-station trials for three years at GKVK, Bengaluru had six treatments each replicated four times in Randomized Block Design (RBD). The treatment combinations were T1 - 1P through Farm Yard Manure (FYM), T2 - 1.5P through FYM, T3 - 1P through pressmud compost, T4 - 1.5P through pressmud compost, T5 - 1P through Single Super Phosphate (SSP), T6 - 0.5P through SSP + 0.5P through pressmud compost.

Application of pressmud compost invariably increased the yields over the same level of P supplied through FYM. The performance of pressmud compost was on par with single super phosphate at recommended level. However, at 1.5P, the yields substantially increased by about 300 kg ha^{-1} in case of ragi and about 100 kg ha^{-1} in case of sunflower. The data

TABLE 7

Yield of crops as influenced by application of pressmud compost at UAS, Bangalore

Treatments	Finger millet (kg ha^{-1})						Sunflower (kg ha^{-1})		
	2004		2005		Mean				
	Grain	Straw	Grain	Straw	Grain	Straw	2004	2005	Mean
1P FYM	1172	2580	1369	2250	1270	2410	556	532	544
1.5P FYM	1515	2740	1638	2410	1560	2570	642	631	637
1P Pressmud Compost	2086	4140	1915	3110	2000	3630	743	859	801
1.5P Pressmud Compost	2659	3980	2163	3360	2410	3670	780	888	834
1P SSP	2248	3930	2029	2810	2140	3370	686	767	727
0.5P SSP + 0.5P Pressmud Compost	2345	4410	2070	3080	2210	3740	631	732	682

(Source: Srinivasmurthy and Patil, 2006)

pertaining to yield of crops as influenced by pressmud compost application depicted in Table 7 (Srinivasamurthy and Patil, 2006).

Tripathi *et al.* (2007) conducted an experiment during 2002-04 to evaluate the response of wheat crop (Raj 3765) and maize crop (Ganga Safed) to pressmud compost prepared from distillery effluent and pressmud.

Chemical composition of pressmud compost revealed that pH of compost was 7.7, EC 12.56 dS m^{-1}, organic carbon 36.33 per cent, nitrogen 1.90 per cent, phosphorus 1.85 per cent, potassium 1.48 per cent, zinc 255.2 ppm, manganese 347.8 ppm, Copper 91.1 ppm and iron 58.57 ppm. Incorporation of pressmud compost alone or in combination with nitrogen and phosphorus fertilizers markedly improved the yield of maize and wheat. The grain yield of wheat recorded highest when pressmud compost was applied at 5 t ha^{-1} with 50 per cent nitrogen and phosphorus fertilizers. The cob yield of maize was highest when pressmud compost was applied at 5 t ha^{-1} with per cent nitrogen and phosphorus fertilizers which was at par with the treatment 2.5 t ha^{-1} pressmud compost with 75 per cent nitrogen and phosphorus fertilizers. Similar result was found by Kumar (2003) at two locations in the research centre of University of California. A blend of 556 kg of pressmud compost and 334 kg of commercial fertilizer ha^{-1} of crop showed higher yield and better potato quality in comparison to a dose of 1359 kg ha^{-1} of N:P:K (19:19:0) fertilizer alone. In another study, the effect of pressmud compost was studied on grape and peach plantation. A dose of 5 t pressmud compost ha^{-1} was applied for five years. The results indicated 10 per cent increase in grapes yield and 25 per cent increase in peach yield.

Significantly higher finger millet grain yield (3752 kg ha^{-1}) was obtained with 100 per cent NPK + RP-PSB enriched pressmud compost at 10 t ha^{-1} (Lavanya, 2019). Grain yield was maximum (3765 kg ha^{-1}) in the treatment RDF + pressmud compost at 10 t ha^{-1} and it was found on par with the application of RDF + Pressmud at 10 ha^{-1} (3699 kg ha^{-1}), RDF + 75 per cent pressmud compost + 25 per cent FYM (3599 kg ha^{-1}) and RDF + 75 per cent Pressmud + 25 per cent FYM (3565 kg ha^{-1}) (Pooja, 2019) **(**Table 8**).** Significantly higher grain and straw yield was recorded in RDF + pressmud compost at 10 t ha^{-1} (3.6 t ha^{-1} and 6.3 t ha^{-1} respectively) (Prabhavathi, 2018).

According to Suma (2018), higher kernel yield (84.98 kg ha^{-1}) and Stover yield (89.34 kg ha^{-1}) in maize were obtained by the application of RDF + pressmud compost 10 t ha^{-1} followed by treatment imposing RDF + Pressmud 10 t ha^{-1} (Table 8).

The results of the experiments conducted by Lingaraju (2018), in maize revealed that significantly higher grain (12440 kg ha^{-1}) and stover (19300 kg ha^{-1}) yield of maize was obtained with application of treated sugar

TABLE 8

Changes in yield and yield attributes as influenced by application of varied levels of pressmud and pressmud compost in finger millet at different growth stages

Treatments	Grain Yield/ Kernel Yield (kg ha^{-1})	Straw Yield/ Stover Yield (kg ha^{-1})	Source
	Fingermillet		
RDF	2541.97	4397.89	POP
100 % NPK + RP-PSB enriched pressmud compost @ 10 t ha^{-1}	3752	6386	Lavanya, 2019
100 % NPK + SSP enriched pressmud compost @ 10 t ha^{-1}	3690	6258	
RDF + Pressmud compost @ 10 t ha^{-1}	3765	6109	Pooja, 2019
RDF + Pressmud @ 10 t ha^{-1}	3699	6073	
RDF + pressmud compost @ 10 t ha^{-1}	3625.14	6363.63	Prabhavathi, 2018
RDF + pressmud @ 10 t ha^{-1}	3594.27	6285.07	
	Maize		
RDF	51.08	55.20	POP
RDF+ Pressmud compost 10 t ha^{-1}	84.98	89.34	Suma, 2018
RDF+ Pressmud 10 t ha^{-1}	79.63	85.01	

Note: DAT – Days after transplanting, FYM – Farm yard manure, RDF – Recommended dose of fertilizer, POP – Package of practice

mill effluent (TSME) with amendment (gypsum) + SSNM for targeted yield of 12000 kg ha^{-1}. In split plot designed experiment kernel and stover yield of maize was recorded higher with the treatment receiving 0.9 IW/CPE ratio with treated sugar mill effluent with sugarcane trash mulching (7980 and 16270 kg ha^{-1}, respectively) compared to other treatment combinations. Treatment with 0.5 IW/CPE ratio with fresh water (5960 and 10010 kg ha^{-1}, respectively) across all the treatments resulted in lower kernel and stover yield (Table 8).

According to Suma (2018), the MWHC of the soil grown with maize increased with increase in the doses of organic sources, significantly higher water holding capacity (39.96 per cent) of the soil was recorded in RDF + pressmud compost at 10 t ha^{-1}, due to application of more quantity of organic manure which enhanced the root biomass, soil organic matter, soil structure, soil porosity, degree of aeration, infiltration, drainage, prevents the soil compaction by deeper penetration of plant roots and increased the water absorption capacity of the soil in maize grown soil.

When phosphorus enriched pressmud compost was applied in finger millet, bulk density of soil varied from 1.46 to 1.48 Mg m^{-3} (Lavanya, 2019). Also the application of varied levels of pressmud, pressmud compost in integration with the chemical fertilizers did not show any significant difference in bulk density of the soil (Pooja, 2019).

According to conducted by study of Prabhavathi (2018), a significant difference in bulk density of soil was observed on application of pressmud and pressmud compost because, application of organics leads to production of polysaccharides that improved soil aggregation and decreased the bulk density.

According to Suma (2018), the bulk density decreased with increase in the doses of the sugar industry solid and FYM in maize field. Application of RDF + pressmud compost at 10 t ha^{-1} recorded lowest bulk density of 1.40 Mg m^{-3} and it was on par with RDF + pressmud at 10 t ha^{-1} and package of practice.

There was no change in the particle density due to application of phosphorus enriched pressmud compost

(Lavanya, 2019) and application of varied level of pressmud and pressmud compost along with recommended dose of fertilizers (Pooja, 2019). Application of different doses of pressmud and pressmud compost also did not show any significant difference in particle density when finger millet was grown (Prabhavathi, 2018) and even in maize grown plots, there was no significance results in particle density due to application of varied levels of sugar industry solid wastes, because texture of the soil cannot be altered (Suma, 2018).

The results of experiment where fingermillet fields were applied with sugar industry solid wastes indicated that there was significant increase in soil pH at 30 days after transplanting when compared to initial pH (7.50) and there was significant decrease in soil pH at different stages of finger millet. There was a slight increase in the pH throughout crop growth due to the application of pressmud and pressmud compost (Pooja, 2019) and no change in the pH due to application of phosphorus enriched pressmud compost. However, pH due to application of phosphorus enriched pressmud compost, varied from 7.71 to 8.01 at 60 days after transplanting and 7.70 to 8.00 at harvest (Lavanya, 2019).

Significant difference in electrical conductivity of soil was observed due to application of phosphorus enriched pressmud compost. Significantly higher EC value (0.28 dS m^{-1}) at 60 days after transplanting was recorded with 100 per cent RDF + Pressmud compost at 10 t ha^{-1} and 100 per cent NPK + RP-PSB enriched pressmud compost at10 t ha^{-1} (Table 9). In case of integrated application of FYM, pressmud and pressmud compost along with the recommended dose of inorganic fertilizers, the electrical conductivity of soil was found to be significantly affected at all stages of crop growth and increased during the vegetative stage of crop growth, but after the harvest of the crop, it decreased. By application of sugar industry solid wastes to fingermillet by Prabhavathi, (2018), there was significant increase in soil electrical conductivity in all the treatments compared to control (0.33 dS m^{-1}), after 30 days of transplanting. Higher soil electrical conductivity was recorded in treatment, RDF

TABLE 9

Soil pH, EC and organic carbon content in experiments applied with different sugar industry wastes sources

Treatments	pH		EC(dS m^{-1})		Organic carbon (per cent)		Source
Fingermillet							
RDF	7.87	7.85	0.18	0.19	0.59	0.56	POP
100 per cent NPK + RP-PSB enriched pressmud compost @ 10 t ha^{-1}	8.01	8.00	0.28	0.30	0.71	0.73	Lavanya, 2019
100 per cent NPK + SSP enriched pressmud compost @ 10 t ha^{-1}	8.00	7.90	0.27	0.28	0.70	0.72	
RDF + Pressmud compost @ 10 t ha^{-1}	7.79	7.71	0.34	0.29	0.71	0.74	Pooja, 2019
RDF + Pressmud @ 10 t ha^{-1}	7.72	7.68	0.33	0.29	0.70	0.73	
RDF + pressmud compost @ 10 t ha^{-1}	7.98	7.96	0.32	0.33	1.40	1.36	Prabhavathi, 2018
RDF + pressmud @ 10 t ha^{-1}	7.97	7.97	0.33	0.26	1.36	1.33	
Maize							
POP	7.53	7.49	0.35	0.32	0.50	0.59	POP
RDF + Pressmud compost 10 t ha^{-1}	7.70	7.66	0.60	0.56	6.34	6.45	Suma, 2018
RDF + Pressmud 10 t ha^{-1}	7.64	7.57	0.44	0.42	6.17	6.26	

RDF: Recommended Dose of Fertilizers, FYM: Farm Yard Manure, POP: Package of Practice

+ pressmud compost at 10 t ha^{-1} (0.54 dSm^{-1}) (Table 9).

According to Prabhavathi (2018), higher soil organic carbon was recorded in RDF + pressmud compost 10 t ha^{-1} recording 1.59 per cent organic carbon and was on par with 1.57 per cent which received RDF + pressmud 10 t ha^{-1} and RDF+ FYM at 10 t ha^{-1} (1.53 %) (Table 9). Organic carbon content increased significantly and was found higher (0.71 and 0.74 per cent at 60 days after transplanting and harvest, respectively). At 60 days after transplanting and at harvest organic carbon content increased significantly and were found higher (0.71 and 0.74 per cent at 60 days after transplanting and harvest, respectively). Significantly higher organic carbon (0.71 per cent and 0.73 per cent at 60 DAT and harvest, respectively) was recorded with 100 per cent NPK + RP-PSB enriched pressmud compost at 10 t ha^{-1} in fingermillet fields (Lavanya, 2019).

Significantly higher nitrogen content (321.56 and 279.30 kg ha^{-1} at 60 DAT and harvest, respectively) was recorded with 100 per cent NPK + RP-PSB enriched pressmud compost at 10 t ha^{-1}. At 60 days after transplanting and at harvest, organic carbon content increased significantly and was found higher (0.71 and 0.74 per cent at 60 days after transplanting and harvest, respectively). But according to Prabhavathi (2018), RDF + pressmud compost at 10 t ha^{-1} recorded significantly higher available nitrogen at 30 DAT (509.7 kg ha^{-1}), 60 DAT (495.5 kg ha^{-1}) and at harvest (309.30 kg ha^{-1}). Phosphorus content was significantly higher (235.68 and 204.35 kg ha^{-1} at 60 DAT and harvest, respectively) with 100 per cent NPK + RP-PSB enriched pressmud compost at 10 t ha^{-1} (Lavanya, 2019).

Significantly higher available phosphorus (195.32 kg ha^{-1} and 173.20 kg ha^{-1} at 60 days after transplanting and harvest, respectively) was recorded in treatment RDF + Pressmud compost at 10 t ha^{-1} (Pooja, 2019). Treatment imposed with RDF + pressmud compost at 10 t ha^{-1} recorded significantly higher available phosphorus at 30 DAT (197.57 kg ha^{-1}), 60 DAT (170.88 kg ha^{-1}) and at harvest (141.47 kg ha^{-1}) (Prabhavathi, 2018). Higher potassium content (426.50

TABLE 10

Available Soil Nitrogen, Phosphorus and Potassium content in experiments applied with different sugar industry wastes sources

Treatments	N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})		Source
			Fingermillet				
RDF	225.92	200.21	0.18	0.19	0.59	0.56	POP
100 per cent NPK + RP-PSB enriched pressmud compost @ 10 t ha^{-1}	321.56	279.30	235.68	204.35	0.71	0.73	Lavanya, 2019
100 per cent NPK + SSP enriched pressmud compost @ 10 t ha^{-1}	307.07	255.21	231.47	201.08	424.07	417.50	
RDF + Pressmud compost @ 10 t ha^{-1}	398.00	382.30	195.30	173.20	467.90	381.00	Pooja, 2019
RDF + Pressmud @ 10 t ha^{-1}	376.40	362.30	191.30	168.20	423.80	374.80	
RDF + pressmud compost @ 10 t ha^{-1}	495.50	309.30	170.88	141.47	291.24	217.68	Prabhavathi, 2018
RDF + pressmud @ 10 t ha^{-1}	489.80	294.10	166.58	136.88	283.40	200.84	
			Maize				
RDF	158.74	124.09	186.18	151.73	234.76	175.17	POP
RDF+ Pressmud compost 10 t ha^{-1}	349.69	301.35	350.41	326.97	377.90	317.35	Suma, 2018
RDF+ PM 10 t ha^{-1}	341.81	294.97	337.94	308.97	350.33	292.24	

RDF: Recommended Dose of Fertilizers, FYM: Farm Yard Manure, POP: Package of Practice

and 418.12 kg ha^{-1} at 60 DAT and harvest, respectively) was recorded significantly with 100 per cent NPK + RP-PSB enriched pressmud compost at 10 t ha^{-1} (Lavanya, 2019) **(**Table 10**)**. But according to the experiment conducted by Prabhavathi (2018), RDF + pressmud compost applied at 10 t ha^{-1} significantly showed higher available potassium at 30 DAT (397.81 kg ha^{-1}), 60 DAT (291.24 kg ha^{-1}) and at harvest (217.68 kg ha^{-1}) but was on par with treatment imposed with RDF + pressmud at 10 t ha^{-1} (361.76, 283.04 and 200.84 kg ha^{-1} at 30, 60 DAT and at harvest, respectively) and RDF + FYM 10 t ha^{-1} (360.53, 283.96 and 200.21 kg ha^{-1} at 30, 60 DAT and at harvest, respectively) **(**Table 10**)**. The available potassium content in the soil increased with increase in the doses of sugar industry wastes according to Pooja (2019) and significantly higher available potassium (467.90 and 381.10 kg ha^{-1} at 60 days after transplanting and harvest, respectively) was recorded in treatment imposed with RDF + PRESSMUD COMPOST at 10 t ha^{-1} (Pooja, 2019) **(**Table 10**)**.

According to Lavanya (2019) significantly higher calcium, magnesium and sulphur uptake by grains (32.48 kg ha^{-1}, 15.50 kg ha^{-1} and 15.87 kg ha^{-1}, respectively) was recorded with 100 per cent NPK + SSP enriched pressmud compost at 10 t ha^{-1}. Higher (10.16 and 10.26 cmol (p+) kg^{-1} of calcium, 7.63 and 7.73 C mol (p+) kg^{-1} of magnesium and 37.43 and 25.04 mg kg^{-1} of exchangeable sulphur at 60 days after transplanting and at harvest, respectively) was recorded in treatment RDF + Pressmud 10 t

TABLE 11

Soil exchangeable Calcium, Magnesium and available Sulphur content in experiments applied with different sugar industry wastes sources

Treatments	Ca[cmol (p+) kg^{-1}]		Mg [cmol (p+) kg^{-1}]		S [mg kg^{-1}]		Source
	60 DAT/S	At harvest	60 DAT/S	At harvest	60 DAT/S	At harvest	
Fingermillet							
RDF	225.92	200.21	0.18	0.19	0.59	0.56	POP
100 per cent NPK + RP-PSB enriched pressmud compost @10 t ha^{-1}	9.69	9.62	3.13	3.01	37.00	32.00	Lavanya, 2019
100 per cent NPK + SSP enriched pressmud compost @ 10 t ha^{-1}	9.72	9.68	3.14	3.12	41.60	33.80	
RDF + Pressmud compost @ 10 t ha^{-1}	10.05	10.13	7.54	7.46	37.43	25.04	Pooja, 2019
RDF + Pressmud @ 10 t ha^{-1}	10.16	10.26	7.63	7.73	35.05	23.15	
RDF + pressmud compost @ 10 t ha^{-1}	12.07	12.67	4.83	2.50	11.95	11.32	Prabhavathi, 2018
RDF + pressmud @ 10 t ha^{-1}	13.40	12.00	5.17	3.00	13.03	12.95	
Maize							
RDF	8.67	7.67	2.53	2.07	21.49	13.59	POP
RDF+ Pressmud compost 10 t ha^{-1}	10.89	9.93	6.45	6.00	44.38	33.96	Suma, 2018
RDF+ pressmud 10 t ha^{-1}	10.67	9.80	5.67	5.33	40.18	30.94	

RDF: Recommended Dose of Fertilizers, FYM: Farm Yard Manure, POP: Package of Practice

ha^{-1} (Pooja, 2019). Higher calcium content was observed in soils imposed with treatments, RDF + pressmud at 10 t ha^{-1}, (13.67 c mol [p+] kg^{-1}) and RDF + pressmud compost at 10 t ha^{-1}, (12.33 c mol [p+] kg^{-1}). RDF + pressmud at 10 t ha^{-1} recorded significantly higher sulphur at 30 DAT (22.99 mg kg^{-1}), 60 DAT (13.03 mg kg^{-1}) and at harvest (12.95 mg kg^{-1}) (Prabhavathi, 2018) **(**Table 11**).**

Significantly higher DTPA extractable iron, zinc and nickel content was noticed with 100 per cent RDF + Pressmud compost at 10 t ha^{-1} (Lavanya, 2019). Significantly higher DTPA extractable manganese and copper content was noticed with 100 per cent NPK + RP-PSB enriched pressmud compost at 10 t ha^{-1} (Lavanya, 2019). Significantly higher iron, copper and manganese contents were recorded in RDF + Pressmud compost at 10 t ha^{-1}. Higher (1.58 and 1.51 mg kg^{-1} at 60 days after transplanting and harvest, respectively) available zinc was recorded with application of RDF + FYM at 10 t ha^{-1}.

According to Prabhavathi (2018), DTPA iron, manganese, zinc and copper at 30 and 60 days in treatment, (RDF + pressmud compost at 10 t ha^{-1}) were high. But The treatment imposed with RDF + pressmud at 10 t ha^{-1} recorded significantly higher boron at 30 DAT (0.76 mg kg^{-1}), 60 DAT (1.39 mg kg^{-1}) and at harvest (0.69 mg kg^{-1}) (Table 12).

In maize fields soil pH did not vary was not varied significantly but electrical conductivity was significantly

TABLE 12

Soil available micronutrients contents in experiments applied with different sugar industry wastes sources

Treatments	Zn (ppm)		Fe (ppm)		Mn (ppm)		Cu (ppm)		Source
	60 DAT/S	At harvest	60 DAT/S	At harvest	60 DAT/S	At harvest	60 DAT/S	At harvest	
				Fingermillet					
RDF	10.21	9.60	4.14	3.65	0.75	0.71	0.82	0.78	POP
100 per cent NPK + RP-PSB enriched pressmud compost @10 t ha^{-1}	15.57	13.98	5.46	5.14	1.53	1.24	1.53	1.47	Lavanya, 2019
100 per cent NPK + SSP enriched pressmud compost @ 10 t ha^{-1}	15.58	13.99	5.41	5.01	1.50	1.18	1.47	1.31	
RDF + Pressmud compost @ 10 t ha^{-1}	15.65	13.91	7.24	7.16	1.54	1.49	1.24	1.17	Pooja, 2019
RDF + Pressmud @ 10 t ha^{-1}	15.31	13.43	6.88	6.74	1.52	1.47	1.32	1.25	
RDF + pressmud compost @ 10 t ha^{-1}	13.51	17.97	5.38	4.86	1.38	1.82	3.59	3.55	Prabha - vathi, 2018
RDF + pressmud @ 10 t ha^{-1}	12.07	15.67	4.75	4.51	1.24	1.43	3.05	3.50	
				Maize					
RDF	9.02	8.45	2.18	2.03	0.76	0.68	0.09	0.07	POP
RDF+ Pressmud compost 10 t ha^{-1}	13.06	11.91	3.15	2.96	1.40	1.30	0.57	0.55	Suma, 2018
RDF+ pressmud 10 t ha^{-1}	12.24	10.72	3.03	2.85	1.32	1.22	0.51	0.48	

RDF: Recommended Dose of Fertilizers, FYM: Farm Yard Manure, POP: Package of Practice

altered. The organic carbon content in soil increased with increase in the doses of organic sources in each stage of crop growth. However, significantly highest organic carbon content (6.10, 6.34 and 6.45 g kg-1 at 30 DAS, 60 DAS and at harvest, respectively) in soil after the harvest of maize crop was recorded in RDF + pressmud compost at 10 t ha^{-1} (Table 9). There was decreasing trade recorded in available nitrogen content in each stage of the crop growth. Significantly highest soil available phosphorus content of 389.51, 350.41 and 326.97 kg ha-1 (30 DAS, 60 DAS and at harvest) was recorded with RDF + pressmud compost at 10 t ha^{-1}. Available potassium content in soil increased with increase in the doses of sugar wastes, significantly higher available potassium (467.98, 377.90 and 317.35 kg ha^{-1} at 30 DAS, 60 DAS and at harvest, respectively) at different interval of maize crop was recorded in the treatment imposed with RDF + Pressmud Compost at 10 t ha^{-1} **(**Table 10**)**.

Maximum content of exchangeable calcium, magnesium and available sulphur was observed in treatment imposed to maize fields with RDF + pressmud compost 10 t ha^{-1} (Table 11). and also DTPA extractable micronutrients like, iron, manganese, copper, zinc and boron were found significantly maximum in treatment RDF + pressmud compost 10 t ha^{-1} (Suma, 2018) (Table 12).

Economics of Pressmud Compost in Alternative Source of Farm Yard Manure

Animal manures were traditionally considered valuable fertilizers and crop production was largely dependent on them. However farm yard manure availability has decreased nowadays. This is because of decrease in practicing animal husbandry, wastage of cow dung as fuel, lacking in the proper shed for cattles, trace amount of nutrient in FYM and other reasons. Fields near to the distillery units can get the sugar industry wastes easily and for less cost than the FYM and they are very rich in nutrients can be used as nutrient source.

Application of 100 per cent NPK + SSP enriched pressmud compost at 10 t ha^{-1}, resulted in higher net return (74737 Rs.ha^{-1}) and benefit cost ratio (2.46) compared package of practice (Lavanya, 2019) (Table 13). pplication of 100 per cent recommended NPK + pressmud compost 10 t ha^{-1} resulted in the higher gross returns (Rs.155300), net returns (Rs.113267) and benefit cost ratio (2.69) compared to package of practice. Hence the application of pressmud compost along with RDF increased the

TABLE 13

Economics of pressmud compost as alternative source of farm yard manure

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs.ha^{-1})	Net return (Rs.ha^{-1})	B:C	Source
		Fingermillet			
100 per cent RDF+ FYM at 10 t ha^{-1} (POP)	30832	101944	71112	2.31	Lavanya, 2019
100 per cent RDF + Pressmud compost at 10 t ha^{-1}	30832	104444	73612	2.39	
RDF + FYM @ 10 t ha^{-1} (POP)	45032	132900	87867	1.95	Pooja, 2019
RDF + 25 per cent Pressmud + 75 per cent FYM	44782	140200	95417	2.13	
RDF + FYM (POP)	31874	105966	74091	2.32	Prabhavathi, 2018
RDF + pressmud compost @ 10 t ha^{-1}	31874	115118	83243	2.61	
		Maize			
RDF+FYM+ZnSO4 (POP)	40726	132535	91809	3.25	Suma, 2018
RDF+ Pressmud compost 10 t ha^{-1}	40226	146646	106420	3.65	

RDF: Recommended Dose of Fertilizers, FYM: Farm Yard Manure, POP: Package of Practice

growth and yield parameters and net profit and integration of pressmud compost along with inorganic fertilizers is an ideal nutrient combination for finger millet in Southern Dry Zone of Karnataka (Pooja, 2019) (Table 13).

Application of RDF + pressmud compost 10 t ha^{-1} was less cost (Rs.31874) and resulted in better gross return (Rs.115118) than the package of practice and its cost was higher (Rs.31874) and gross return was lesser (Rs.105966), which was more than the yield obtained from the crop grown with package of practice (Prabhavathi, 2018) (Table 13).

According to Suma (2018) in maize crop, the package of practice recommendation recorded highest cost of cultivation (Rs.40726 ha^{-1}) and less gross return (Rs.132535 ha^{-1}) than the crop grown with treatment imposed with, RDF + Pressmud compost at 10 t ha^{-1} whose cost was Rs.40226 and with gross return of Rs.146646 **(**Table 13**)**.

Combined application of sugar solid waste, FYM and inorganic fertilizers helped in balanced nutrition, increase in various physiological processes and increase in availability of major, secondary and other micronutrients, which ultimately resulted in improved growth, yield and profit. Sugar industry wastes are very good nutrient sources, application of the same avoid the environmental pollution, give higher yield with more profit and is a great solution for disposal of sugar industry wastes.

In case of finger millet and maize, treatment imposed with RDF + pressmud compost at 10 t ha^{-1} gave good yield at less cost having highest benefit:cost ratio. So, farmers can apply 10 tonnes of pressmud compost per hectare with recommended dose of chemical fertilizer for better profit and also good soil properties in finger millet and maize crops.

Use of treated effluents from distillery industries as a nutrient application in wide range of agricultural crops is interesting task. The results indicates that, application of treated effluents released from the distilleries to different crops have been investigated over the years and found that majority of studies showing increase in the crop growth and yield without any harm to the soil properties. Recycling of organic wastes in agriculture brings in the much-needed organic and mineral matter to the soils and leads to an improvement in overall soil productivity of which soil fertility is a key component.

Extensive research work has been carried out on treatment of distillery spent wash in many parts of the world. It is learnt that spent wash is a valuable resource which is essentially a plant extract derived from the sugarcane (in case of molasses) besides microbial residues. It is rich in organic matter like N, P, K, Ca, S and micronutrients such as iron, Zn, Cu, Mn, B and Mo. The distillery spent wash is highly effective in improving the physico-chemical properties and nutritional status of drylands and sandy soils.

One time application diluted with irrigation water is beneficial to crop plants in arable agricultural land. Whereas, the pressmud compost produced from the aerobic decomposition along with the microbial culture as a catalyst would help in composting of pressmud and spent wash which is superior as an organic manure and soil amendment to increase the nutritive value of an intensively cultivated soil.

Application of sugar industry by-products along with recommended dose of fertilizers is highly effective in improving the yield so that crops can be grown with less cost and also gross returns will be high. This in turn avoids the pollution created by the sugar industry by-products and give solution for disposal of wastes.

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Future Line of Work

1. Spent wash is a valuable nutrient source containing all the plant nutrients and hence studies are necessary to evaluate spent wash as liquid manure for foliar application

2. Some distilleries are not interested to go for bio-methanation but straight away use the raw spent wash for composting and directly release to water bodies. Hence there is a necessity to create awareness among distilleries regarding importance of treating of raw spent before releasing to water bodies or using it for composting.

3. Awareness should be created among farmers in dry land areas regarding the use of treated spent wash as a source of irrigation water since it is rich in various macro and micro nutrients and also serve as an alternative source of water in scarce areas

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