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Impact of Distillery Spent wash application on soil health under Pearl millet crop

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ABSTRACT

The Post Biomethanated Distillery Spent wash (PBDSW) is effective organic liquid manure derived from sugar industry waste materials. Spent wash contains high amount of nutrients like Nitrogen, Phosphorus, Potassium, Calcium and Sulfur. In addition, it contains sufficient amount of micronutrients such as Iron, Zinc, Copper, Manganese, Boron and Molybdenum. The land application of spent wash offers benefits of water pollution control and utilization for agricultural production. The field experiment was conducted with different doses of Post Biomethanated Distillery Spent wash (PBDSW) as a source of nutrients in various proportions with inorganic fertilizer under pearl millet crop. The highest mean value of soil organic carbon (0.73 per cent) was recorded in T_2 (PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK) (0.73 per cent). The soil available Nitrogen, Phosphorus and Potassium markedly increased due to the application of distillery spent wash. The mean available NPK content ranged from 165.0 to 203.6 kg ha^{-1}, 16.8 0 to 20.40 kg ha^{-1} and 237.33 to 493.33kg ha^{-1} respectively. Spent wash application significantly improved the enzymatic activity (Urease, phosphatase and dehydrogenase) compared to the control treatment which enhance the soil health in turn crop productivity.

Key words : *Distillery Spent wash, Soil, Application, Health*

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 of largest volumes (for every litre of alcohol produced 15 litres of waste liquid produced) is discharged as wastewater, generally known as spent wash. Although different terminologies *viz.,* stillage, vinasse, slop, bottom slop, still residue are used for this type of effluent in different countries, stillage and vinasse are the most common terms used in most of the European and South American countries. The term under is used in Australia while the term distillery effluent is used in other countries.

Distilleries have become a major source of pollution as 88 per cent of the raw materials are converted into waste and discharged into the water bodies causing water pollution. For every liters of alcohol production 10-15 litres of waste water (spent wash) is generated which poses a serious disposal problem (Bhardwaj *et al*., 2019; Kaloi *et al*., 2017)

In recent years, the demand for waste water reuse has increased significantly worldwide. In particular, the arid and semiarid areas of the world can easily augment 15-20 per cent of their water supply through reuse of waste water. Agriculture being

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water driven practice is major sufferer of water scarcity and in future condition will be more severe. Reuse of wastewater in agriculture can augment some sort of water demand. Such water reuse accomplishes several purposes such as minimizing the cost of waste water treatment and disposal, providing much needed nutrients and fertilizer to soil when used for agriculture (Jayashree *et al*., 2022; Chattha *et al*., 2018).

About 285 distilleries are presently operating in India, which produce about 2.75 billion gig litres (GL) of alcohol and 30-45 GL of spent wash (as a by-product) per year and in Tamil Nadu, there are 41 sugar factories and 22 distilleries with a total installed capacity of 2.4 lakhs kilolitres of alcohol.

Since the production of wastewater in distilleries is a continuous process, it can cater for substantial irrigation requirements, where shortage of water becomes limiting factor (Fito *et al*., 2019; Shinde *et al*. 2021). In some water scarce areas, farmers use the effluent as a substitute for irrigation water but over the years its use has led to the realization of its fertilizer potential also. Various workers from their studies have suggested suitable application rates for distillery effluent for ferti-irrigation purposes and crop-specific nature of effluent. Effluent from distilleries contains a large amount of dissolved organic matter. This organic matter is readily decomposed by biological action. The utilization of industrial waste as soil amendment has generated interest in recent times. Most crops give higher potential yields with wastewater irrigation and reduce the need for chemical fertilizers, resulting in net cost savings to farmers.

Materials and Methods

Collection and preservation of samples

The spent wash samples were collected from the M/s Sakthi Sugars Ltd. (Distillery Division) at Aapakudal, Erode District, Tamil Nadu. The Post Biomethanated Distillery Spent wash (PBDSW) was collected in polycarboryl containers, properly sealed and stored at 4 °C for the analysis of physico-chemical properties (APHA, 2012)

Field Experiment

Field experiment was conducted at Research and Development Farm, M/s Sakthi Sugars Ltd., Sakthi Nagar, Erode district, Tamil Nadu in order to study the effect of distillery spent wash application on the physico-chemical properties of soil. The treatment details are T_1-Control – 100% recommended dose of NPK. T_2-PBDSW at the rate of 100 KL ha^{-1} and recommended dose of NPK, T_3 -PBDSW at the rate of 100KLha^{-1}in split application and recommended dose of NPK, T_4-50% K through PBDSW and Remaining N, P, K through inorganic source T_5-100% K substitution through PBDSW and Remaining N, P through inorganic source. After 15 days, the treated plots were inverted manually with spade to facilitate aeration and oxidation, and then plots were formed. In all the plots, entire phosphorus and half dose of nitrogen as per the treatments were applied as basal while remaining nitrogen as per the treatments was applied in two equal splits on 30th and 45th day after sowing. The soil samples were collected at initial, 30,60 and 90 days after sowing of pearl millet and analysed for changes in the physico-chemical properties of soil in pearl millet field.

Results and Discussion

Characteristics of experimental soil

The initial soil samples were collected from the experimental field before the applications of Post Biomethanated Distillery Spent wash (PBDSW) and were analyzed. The results (Table 1) indicated that the bulk density and particle density and of initial

Table 1. Characteristics of the experimental soil

Parameters	Values*
Physical composition	
Bulk density (Mg m^{-3})	1.37
Particle density (Mg m^{-3})	2.38
Chemical composition	
pH	7.15
EC (dS m^{-1})	0.43
Organic carbon (per cent)	0.45
Available N (kg ha^{-1})	160
Available P (kg ha^{-1})	16.3
Available K (kg ha^{-1})	235
Exchangeable Ca [cmol (p$^+$) kg^{-1}]	6.38
Exchangeable Mg [cmol (p$^+$) kg^{-1}]	2.50
Exchangeable Na [cmol (p$^+$) kg^{-1}]	0.88
Exchangeable K [cmol (p$^+$) kg^{-1}]	0.27
DTPA - Zn (mg kg^{-1})	0.82
DTPA - Cu (mg kg^{-1})	1.10
DTPA - Mn (mg kg^{-1})	4.20
DTPA - Fe (mg kg^{-1})	3.30

*Mean of three samples

soil were 1.37 Mg m^{-3} and 2.38 Mg m^{-3} respectively.

The initial soil pH (7.15) was neutral and the EC was 0.43 dS m^{-1}. The organic carbon content was 4.5 g kg^{-1}. Among the three macronutrients, NH_4OAc-K was found in higher amounts (235 kg ha^{-1}), followed by $KMnO_4$N (160 kg ha^{-1}) and Olsen-P (16.3 kg ha^{-1}). The exchangeable calcium, magnesium, sodium and potassium were 6.38, 2.50, 0.88 and 0.27 cmol (p^+) kg^{-1} respectively. Among the micronutrients, low level of Zn was recorded (0.80 mg kg^{-1}), while Mn, Fe and Cu were found to be 4.00, 3.00 and 01.10 mg kg^{-1}, respectively.

Effect of Post Biomethanated Distillery Spentwash (PBDSW) application on soil properties of pearl millet crop field

pH

All the treatments recorded higher pH than the control - RDF (Table 2). There is no significant difference ($p>0.05$) in the soil pH observed between different treatments in different stages of crop growth. The highest mean pH of 7.89 was observed in the treatment that received PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK (T_2). The pH of 7.11 was recorded in T_1 (control – RDF) which lesser when compared to all other treatments. The mean pH ranged from 7.41 at 90DAS to 7.54 at 30DAS). During decomposition, as the spent wash reacts with the soil minerals dissolving large amounts of Ca, Al and Fe, some of which are subsequently precipitated as new compounds resulted in increase of soil pH. Addition of base materials like calcium from spent wash also has increased the pH (Shinde *et al*., 2021).

EC

The treatments significantly ($P<0.05$) influenced the EC of the soil. The EC of the soil progressively increased with increasing doses of PBDSW at all stages of crop growth. The EC of the soil varied from 0.48 to 0.73 dS m^{-1}. The lowest mean value of soil EC (0.45dS m^{-1}) was recorded in T_1 (control – RDF) and the highest value (0.71 dS m^{-1}) was recorded in T_2 (PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK). A decrease in EC value was observed as the days progressed and the mean EC ranged from 0.56 dS m^{-1}at 90DAS to 0.61 dS m^{-1} 30DAS respectively. Bhaskar *et al.* (2018) also reported that the application of distillery effluent increased the electrical conductivity of the soil.

Organic Carbon

The organic carbon content of the soil ranged from 0.53 to 0.77 per cent. The highest mean value of soil organic carbon (0.73 per cent) was recorded in T_2 (PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK) (0.73 per cent), followed by T_3 (PBDSW at the rate of 100KL ha^{-1} in split dose along with recommended dose of NPK) of 0.60 per cent. The lowest value of soil organic carbon (0.49 per cent) was recorded in T_1 (control - RDF). A decreasing trend in mean soil organic carbon was evident at vegetative state (0.65 per cent) to harvest stage (0.58 per cent) of the pearl millet crop. (Table 2). The effectiveness of spentwash in increasing the organic carbon content was also reported by many workers (Naroem *et al*., 2017)

Available NPK

The soil available Nitrogen, Phosphorus and Potassium markedly increased due to the application of distillery spent wash. The mean available NPK content ranged from 165.0 to 203.6 kg ha^{-1}, 16.8 0 to 20.40 kg $ha^{-1}$and 237.33 to 493.33kg ha^{-1} respectively. There was a decreasing trend in soil available N, P and K of the pearl millet crop as the crop growth

Table 2. Effect of PBDSW on soil pH, EC and Organic Carbon at various stages of pearl millet

Treatment/ Stages	pH				EC (dS m^{-1})				Organic carbon (%)			
	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean
T_1	7.15	7.11	7.08	7.11	0.48	0.45	0.43	0.45	0.53	0.49	0.45	0.49
T_2	7.98	7.87	7.82	7.89	0.73	0.71	0.68	0.71	0.77	0.72	0.69	0.73
T_3	7.76	7.64	7.55	7.65	0.67	0.65	0.63	0.65	0.64	0.60	0.56	0.60
T_4	7.43	7.39	7.34	7.39	0.61	0.59	0.58	0.59	0.72	0.69	0.63	0.68
T_5	7.36	7.29	7.25	7.30	0.55	0.52	0.50	0.52	0.61	0.59	0.57	0.59
Mean	7.54	7.46	7.41	7.47	0.61	0.58	0.56	0.59	0.65	0.62	0.58	0.62
Sed	NS	NS	NS		0.03	0.03	0.02		0.03	0.02	0.02	
CD	NS	NS	NS		0.06	0.06	0.05		0.06	0.04	0.05	

progressed. The mean available N at pearl millet growth stages ranged from 90DAS-173.8 kg ha^{-1} to 30DAS-184.4 kg ha^{-1}, available P ranged from 90DAS- 16.0 kg $ha^{-1}$to 60DAS -17.1 kg ha^{-1} and available K in the soil ranged from 90DAS –349.8 kg ha^{-1} to 30 DAS– 389.0 kg ha^{-1}.The highest mean value of soil available N, P and K (203.6, 20.4 and 493.33kg ha^{-1}) were recorded in T_2 (PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK), followed by T_3(PBDSW at the rate of 100KL ha $^{-1}$ in split dose along with recommended dose of NPK) which was significantly ($p<0.05$) different from other treatments. The control - RDF recorded (T_1) the least mean value of 165,16.8 kg ha^{-1} and 237.33 of N, P and K respectively (Table 3). An increase of 3.6 kg ha^{-1} of available P when compared to control was recorded due to application of PBDSW at the rate of 100KL ha^{-1}(T_2) along with recommended dose of NPK. The significant increase of available P in soil might be due to the addition of P and HCO_3 through PMDSW application and production of organic acids during the decomposition of PMDSW would have helped to solubilize the native soil phosphorous. Similar results were reported by Singh *et al.* 2016. A remarkable increase in the availability of N, P and K content of both in the treated and raw spent wash was also reported by many workers (Singh *et al.*, 2016).

Exchangeable Ca

The exchangeable calcium content of the soil (Table 4) was influenced by different treatments. The treatment that received PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK (T_2) recorded the highest mean exchangeable calcium content of 9.21cmol (p^+) kg^{-1} and the minimum calcium content of 5.21 cmol (p^+) kg^{-1} was recorded in control - RDF. A decrease in Calcium content in the soil was observed as the days progressed and the mean Ca content ranged from 7.59 cmol (p^+) kg^{-1} at 90DAS to 7.84 cmol (p^+) kg^{-1}at 30 DAS respectively.

Exchangeable Mg

The highest mean exchangeable magnesium content of 3.77 cmol (p^+) kg^{-1} was recorded in the treatment that was applied with PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK (T_2) (Table 4). The control - RDF recorded the lowest soil exchangeable Mg content of 2.15 cmol (p^+) kg^{-1}, which was significantly ($p<0.05$) lesser when compared to all other treatments. The mean available magnesium content in soil at pearl millet growth stages ranged from 3.20 cmol (p^+) kg^{-1} at 90DAS to 3.28 cmol (p^+) kg^{-1}at 30 DAS respectively.

Table 3. Effect of PBDSW on soil available macronutrients content at various stages of pearl millet

Treatment/	Available N (kg ha^{-1})				Available P (kg ha^{-1})				Available K (kg ha^{-1})			
Stages	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean
T_1	169.0	165.0	161.0	165.0	18.0	17.1	15.5	16.8	260.0	232.0	220.0	237.33
T_2	211.0	202.0	198.0	203.6	19.2	21.7	20.5	20.4	515.0	489.0	476.0	493.33
T_3	188.0	182.0	178.0	182.7	18.3	22.0	19.8	20.0	443.0	430.0	418.0	430.33
T_4	179.0	173.0	168.0	173.3	13.1	12.9	12.7	12.9	374.0	360.0	348.0	360.67
T_5	175.0	170.0	164.0	169.7	12.3	11.9	11.5	11.9	353.0	321.0	287.0	320.33
Mean	184.4	178.4	173.8	178.7	16.2	17.1	16.0	16.4	389.0	366.4	349.8	368.40
Sed	9.54	9.21	8.90		0.90	0.80	0.70		20.93	19.79	19.04	
CD	20.80	20.08	19.60		1.90	1.80	1.50		45.00	43.12	41.47	

Table 4. Effect of PBDSW on soil exchangeable Ca and Mg content at various stages of pearl millet

Treatment /	Exchangeable Ca (cmol (p^+) kg $^{-1}$)				Exchangeable Mg (cmol (p^+) kg $^{-1}$)			
Stages	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean
T_1	5.50	5.42	5.21	5.38	2.00	2.31	2.15	2.15
T_2	9.42	9.34	9.21	9.32	3.82	3.78	3.72	3.77
T_3	8.91	8.84	8.72	8.82	3.74	3.70	3.62	3.69
T_4	7.73	7.59	7.44	7.59	3.52	3.43	3.30	3.42
T_5	7.66	7.52	7.39	7.52	3.31	3.29	3.23	3.28
Mean	7.84	7.74	7.59	7.73	3.28	3.30	3.20	3.26
Sed	0.41	0.41	0.39		0.16	0.15	0.16	
CD	0.89	0.88	0.86		0.37	0.35	0.36	

Exchangeable Na

The soil exchangeable sodium was influenced the application of distillery spent wash. The mean value of Na ranged from 1.00 to 1.43 cmol (p^+) kg^{-1}. The maximum mean value of soil exchangeable Naof 1.43 cmol (p^+) kg^{-1} was registered in T_2 (PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK). The minimum value of 1.00 cmol (p^+) kg^{-1}was registered in T_1 (control - RDF), which was significantly $p<0.05$) lower than other treatments. The mean Na content in soil ranged from 1.17 cmol (p^+) kg^{-1} at post-harvest stage (90 DAS) to 1.27 cmol (p^+) kg^{-1} at the vegetative stage (30 DAS) to of pearl millet crop (Table 5).

Exchangeable K

The exchangeable potassium content of the soil (Table 5) was influenced by different treatments. The treatment that received PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK (T_2) recorded the highest mean exchangeable potassium content of 0.52cmol (p^+) kg^{-1} and the minimum exchangeable potassium content of 0.27 cmol (p^+) kg^{-1} was recorded in control - RDF. There was a decrease in mean exchangeable K content as the days progressed and the mean exchangeable Na content ranged from 0.35 cmol (p^+) kg^{-1} (90DAS) to 0.39 cmol (p^+) kg^{-1}(30DAS).

The application of vinasse increased the CEC, K, Ca, and Mg content of the soil, which might be due to addition of K, Ca and Mg either through the effluent addition (Ghosh ray and Gangrukha, 2018; Nawaz *et al*., 2019; Choudhary *et al*., 2017;Vadivel *et al*., 2019) or the solubilising effect of distillery effluent on the unavailable native forms

Effect of PBDSW application on soil enzyme activities

Dehydrogenase activity

The dehydrogenase activity of the soil was highly influenced by different doses of PBDSW application. Significantly ($p<0.05$) higher mean dehydrogenase activity of 25.40 and 22.53 μg of TPF g^{-1} of soil h^{-1} was recorded in T_2 and T_3, which were on par with each other. The lowest mean enzyme activity of 14.57 μg of TPF g^{-1} of soil h^{-1} was recorded in T_1 (Control - RDF). The mean dehydrogenase enzyme activity was lowest (17.2 μg of TPF g^{-1}of soil h^{-1}) at

Table 5. Effect of PBDSW on soil exchangeable Na and K content at various stages of pearl millet

Treatment /	Exchangeable Na (cmol (p^+) kg $^{-1}$)				Exchangeable K (cmol (p^+) kg $^{-1}$)			
Stages	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean
T_1	1.09	0.98	0.92	1.00	0.28	0.27	0.26	0.27
T_2	1.47	1.44	1.39	1.43	0.53	0.52	0.50	0.52
T_3	1.42	1.37	1.35	1.38	0.47	0.46	0.45	0.46
T_4	1.21	1.17	1.10	1.16	0.35	0.33	0.29	0.32
T_5	1.16	1.13	1.07	1.12	0.30	0.27	0.23	0.27
Mean	1.27	1.22	1.17	1.22	0.39	0.37	0.35	0.37
Sed	0.06	0.05	0.06	0.02	0.03	0.02		
CD	0.14	0.13	0.14	0.04	0.06	0.04		

Table 6. Effect of PBDSW on soil enzyme activity at various stages of pearl millet

Treatment/ Stages	Dehydrogenase (μg TPF g^{-1} of dry soil hr^{-1})				Phosphatase (μg P-NPP g^{-1} of dry soil hr^{-1})				Urease (μg NH_4-N g dry soil hr^{-1})			
	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean	30 DAS	60 DAS	90 DAS	Mean
T_1	17.0	14.9	11.8	14.57	21.3	18.5	15.9	9.97	14.1	13.2	12.7	13.33
T_2	27.0	25.4	23.8	25.40	22.4	20.8	19.2	20.80	18.0	16.0	13.5	15.83
T_3	24.1	22.2	21.3	22.53	21.3	19.0	17.1	9.97	17.3	15.5	13.7	15.50
T_4	22.1	20.3	17.0	19.80	19.1	16.2	13.7	16.33	16.0	14.1	11.2	13.77
T_5	18.0	15.8	12.3	15.37	18.2	15.1	10.3	14.53	15.0	13.1	10.9	13.00
Mean	21.6	19.7	17.2	19.53	20.5	10.6	11.9	14.32	16.1	14.4	12.4	14.29
Sed	1.14	1.05	0.94		1.16	0.94	0.83		0.82	0.74	0.64	
CD	2.50	2.29	2.06		2.3	2.05	1.80		1.80	1.62	1.40	

harvest stage (90DAS) and highest (21.60 µg of TPF g^{-1} of soil h^{-1}) at vegetative stage (Table 6).

Phosphatase activity

The phosphatase activity of the soil was highly influenced by different doses of PBDSW application. Significantly ($p<0.05$) higher mean phosphatase activity of 20.80 µg of PNPP g^{-1} of soil h^{-1} was recorded in T_2 (PBDSW at the rate of 100KL ha^{-1} along with recommended dose of NPK), followed by the treatments T_3, T_4 and T_5. The lowest enzyme activity of 9.97 µg of PNPP g^{-1} of soil h^{-1} was recorded in T_1 (Control - RDF). The soil phosphatase activity significantly ($p<0.05$) differed at all stages of pearl millet crop growth. The enzyme activity was lowest at 90DAS (harvest stage) of 11.9 µg of PNPP g^{-1} of soil h^{-1} and the highest at S_1 (Vegetative stage) of 20.46 µg of PNPP g^{-1} of soil h^{-1} (Table 6).

Urease activity

Urease activity of the soil was measured in distillery spent wash applied field. Significantly ($p<0.05$) higher mean urease activity of 15.83 µg of ammonia released g^{-1} of soil hr^{-1} was recorded in T_2 (PBDSW at the ra te of 100KL ha^{-1} along with recommended dose of NPK), which was on par with T_3 (PBDSW at the rate of 100KL ha $^{-1}$ in split dose along with recommended dose of NPK) of 15.50 µg of ammonia released g^{-1} of soil hr^{-1}. The lowest enzyme activity of 13.33 µg of ammonia released g^{-1} of soil hr^{-1} was recorded with T_1 (Control - RDF). The soil urease activity significantly ($p<0.05$) differed at all stages of crop growth. The enzyme activity was the lowest (12.4 µg of ammonia released g^{-1} of soil hr^{-1}) at harvest stage (90DAS) of and the highest (16.1 µg of ammonia released $g^{-1}$of soil hr^{-1}) at vegetative stage (30DAS) of (Table 6). Similarly, Hassan *et al*. (2021) reported that the application of DSW significantly improved the enzymatic activity compared to the control treatment, which can cause a significant improvement in the crop performance. The application of DSW significantly improved the phosphatase activity at various stages of crop growth. Dehydrogenase enzyme is considered as an imperious indicator for soil biological activities. DWS application results in an increase in the urease activity. Such an increase in the activity of dehydrogenase can be due to the increase in OM, nutrients, and microbial biomass (Kumar Bhara *et al*., 2017; Vadivel *et al*., 2017). The application spent wash enhance the soil health and crop productivity.

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