



## Long-term effect of bio-methanated spentwash irrigation on soil organic carbon and nutrient status in a vertisol

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**Abstract:** A field experiment was conducted at the Ugar Sugar Factory premises, Ugar-Khurd, Belgaum district to study the effect of long-term application of bio-methanated spentwash on nutrient status under Northern Dry Zone (Zone-III) of Karnataka. The data on soil organic carbon, available major (N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O) and micronutrients (Zn, Fe, Mn and Cu) showed progressive increase in all the parameters due to continuous spentwash irrigation for varied periods of time. The status of organic carbon and available nutrients was maximum in the treatment that received spentwash for > 20 years, while lower status was observed in control treatment.

**Key words:** Vertisol, Bio-methanated spentwash, Long-term application, Organic carbon, Nutrient status

### Introduction

Spentwash is a light brown coloured non-toxic liquid containing residual nutrients from sugarcane and yeast cells with rotten jaggery smell. Distillery effluent is characterized by neutral pH, high EC, high biological oxygen demand and chemical oxygen demand and contains a high percentage of essential nutrient elements and application of this primary treated spentwash on land offers a promising alternative as irrigation water and as a source of plant nutrients while offering solutions to the disposal problem. India is a major producer of sugar and its by-products. It is one of the significant exporters of sugar in the world and contributes substantially to economic development. Molasses is an important by-product from the sugar industries which is formed after the crystallization of sugar. Molasses is a chief source for the production of alcohol in the distilleries by fermentation method. Sugarcane based industries are increasing exponentially and many factories adjunct with distillery in order to balance the price of sugar in open market besides enhancing energy security to the country.

Application of industrial wastes as fertilizer and soil amendment has become popular in agriculture. Irrigation water quality is believed to have effects on the soil and agricultural crops. As the effluent is mainly a plant extract, rich in organic matter and plant nutrients like potassium, nitrogen, sulphur and calcium, there is a scope for using it advantageously as a source for ferti-irrigation to agricultural crops. Raw spentwash has a low pH of 3.0-5.4, high EC of 5-23.7 dS m<sup>-1</sup>, high BOD of 32,800- 43,200 mg L<sup>-1</sup> and high COD of 76,000- 1,08,000 mg L<sup>-1</sup> (Hati, *et. al.*, 2007) and is not suitable for irrigation directly. The BOD and COD were reduced through the bio-methanation process and then used for irrigation with dilution. This study considered the plots irrigated continuously with bio-methanated spentwash and the effect of such practice on soil organic carbon and nutrient status in a Vertisol.

### Material and Methods

The bio-methanated spentwash (dilution 1:10) was used as irrigation source to sugarcane @ 100 m<sup>3</sup> ha<sup>-1</sup> year<sup>-1</sup>. The physico-chemical characteristics of the bio-methanated spentwash is given the Table 1. The soil of the experimental site was calcareous medium deep Vertisol. The soil was alkaline in nature with pH ranging from 7.84 to 8.11. The experiment was laid-out in 2-factor RCBD. The treatments included bio-methanated spentwash irrigation for varied periods of time (factor-1); P<sub>0</sub>: Control, P<sub>1</sub>: 5-10 years, P<sub>2</sub>: 10-15 years, P<sub>3</sub>: 15-20 years and P<sub>4</sub>: >20 years at different soil depths (factor-2); D<sub>1</sub>: 0-20 cm, D<sub>2</sub>: 20-40 cm, D<sub>3</sub>: 40-60 cm, D<sub>4</sub>: 60-80 cm and D<sub>5</sub>: > 80 cm. Soil samples were collected from these long-term spentwash irrigated fields for varied periods of time and from different depths to study the effect of such practice on soil organic carbon and nutrient status of soil. Standard procedures were followed for the estimation of soil organic carbon, available NPK, and micronutrients. Available nitrogen in soil was estimated by modified alkaline permanganate oxidation method as outlined by Sharawat and Burford (1982). Available Zn, Cu, Fe and Mn were determined by following Lindsay and Norvell (1978) procedure using DTPA extractant. The concentration of Zn, Cu, Fe and Mn in the filtrate was read in atomic absorption spectrophotometer. Available potassium was extracted with neutral normal ammonium acetate (pH 7.0) and the content of potassium in the extractant was estimated as described by Sparks (1996) using flame photometer. Available phosphorus in soil was extracted using Olsens extractant (NaHCO<sub>3</sub>) and stannous chloride was used for development of blue colour. The intensity of blue colour was read using spectrophotometer at 660 nm wavelength (Sparks, 1996).

### Results and Discussion

The mean soil organic carbon content (Table-2) showed significant differences among treatments and soil depths. Increased

periods of spentwash application resulted in increase in organic carbon content of soil. The highest organic carbon content ( $8.1 \text{ g kg}^{-1}$ ) was noticed in the treatment that received spentwash for > 20 years as compared to rest of the treatments. The lowest organic carbon content ( $2.8 \text{ g kg}^{-1}$ ) was observed in control. The soil organic carbon was higher at the surface and decreased with depth. Across spentwash treatments, organic carbon was higher in the surface (0-20 cm) ( $11.1 \text{ g kg}^{-1}$ ) and decreased significantly with increasing depth and recorded the lowest at >80 cm depth ( $1.5 \text{ g kg}^{-1}$ ). Long-term spentwash irrigation favoured build-up of available nitrogen in soil. The treatment where the crop was irrigated with spentwash > 20 years recorded the highest available nitrogen ( $147.9 \text{ kg ha}^{-1}$ ). However, it remained on par with the  $P_1$  (5 to 10 years),  $P_2$  (10 to 15 years of spentwash application) and  $P_3$  (15 to 20 years) with the value of 135.3, 144.9 and  $139.6 \text{ kg ha}^{-1}$  respectively. The lowest available nitrogen was observed in control ( $93.9 \text{ kg ha}^{-1}$ ). The soil available nitrogen was higher at the surface and decreased with depth. The surface soil (0-

20 cm) registered the highest the available nitrogen ( $217.9 \text{ kg ha}^{-1}$ ) while the lowest was registered at > 80 cm depth ( $77.4 \text{ kg ha}^{-1}$ ).

The interaction effect of different periods of spentwash application and soil depths was significant with respect to organic carbon content and available nitrogen in soil. Both soil organic carbon and available nitrogen increased with increasing periods of spentwash irrigation, recording the highest status with > 20 years of its continuous use. Similar result was reported by Kumar and Chopra (2011). Tripathi *et al.* (2011) also inferred that soil organic carbon increased significantly due to spentwash irrigation. Even though spentwash contained only small quantity of nitrogen, its long-term application increased the available nitrogen status of the soil. Bose *et al.* (2002) reported similar findings wherein spentwash application significantly increased the available nitrogen content of post-harvest soil. This was ascribed to its direct contribution to N supply and indirectly through addition of organic matter, which in turn enhanced microbial activity and increased the available N pool. Spentwash acted as a slow releasing liquid nitrogen fertilizer. The control field recorded lower available nitrogen compared to the spentwash applied plots.

As like in case of nitrogen, the available phosphorus ( $27.38 \text{ kg ha}^{-1}$ ) was significantly higher with spentwash irrigation for >20 years (Table 3). Significantly the lowest available phosphorus ( $13.53 \text{ kg ha}^{-1}$ ) was observed in control. As the soil depth increased, available phosphorus decreased in all the treatments. The available phosphorus ( $28.37 \text{ kg ha}^{-1}$ ) was significantly higher in 0-20 cm depth and the lowest available phosphorus ( $15.54 \text{ kg ha}^{-1}$ ) was observed in >80 cm depth. The effect of different treatments on available potassium status was similar to that of phosphorus. The higher available potassium ( $504.12 \text{ kg ha}^{-1}$ ) was recorded with > 20 years spentwash irrigation, while the lowest ( $200.56 \text{ kg ha}^{-1}$ ) in control treatment. With increased soil depth there was decrease in available potassium in all the treatments. There interaction effect was significant between different periods of spentwash application and soil depths in respect of available potassium and phosphorus status of the soil.

Soils irrigated with spentwash recorded higher phosphorus content than un-irrigated field was due to addition of phosphorus through spentwash in the organic form that mineralized to inorganic upon decomposition. The soil organic matter acted as a substrate

**Table-1:** Characteristics of distillery bio-methanated spentwash

Parameter	Value
Colour	Light brown
Odour	Tolerable
pH	7.37
Electrical conductivity (dS $\text{m}^{-1}$ )	17.32
Biological oxygen demand (mg $\text{L}^{-1}$ )	7,200
Chemical oxygen demand (mg $\text{L}^{-1}$ )	18,032
Bicarbonates (mg $\text{L}^{-1}$ )	3.9
Carbonates (mg $\text{L}^{-1}$ )	Trace
Chlorides (mg $\text{L}^{-1}$ )	3266
Sodium (mg $\text{L}^{-1}$ )	234
Potassium (mg $\text{L}^{-1}$ )	6213.12
Calcium (mg $\text{L}^{-1}$ )	521
Magnesium (mg $\text{L}^{-1}$ )	233
Total nitrogen (mg $\text{L}^{-1}$ )	748
Total phosphates (mg $\text{L}^{-1}$ )	112.35
Zinc (mg $\text{L}^{-1}$ )	8.34
Iron (mg $\text{L}^{-1}$ )	21.25
Manganese (mg $\text{L}^{-1}$ )	4.35
Copper (mg $\text{L}^{-1}$ )	6.55

(Source: Personal communication, Ugar Sugar Factory, Belgaum, Karnataka)

**Table-2:** Effect of different periods of spentwash application on soil organic carbon and available nitrogen

Soil depth (cm)	Organic carbon (g $\text{kg}^{-1}$ )					Available N (kg $\text{ha}^{-1}$ )						
	Control ( $P_0$ )	Periods of spentwash application (years)				Mean	Control ( $P_0$ )	Periods of spentwash application (years)				Mean
		5-10 ( $P_1$ )	10-15 ( $P_2$ )	15-20 ( $P_3$ )	>20 ( $P_4$ )			5-10 ( $P_1$ )	10-15 ( $P_2$ )	15-20 ( $P_3$ )	>20 ( $P_4$ )	
0-20 ( $D_1$ )	6.0	8.2	11	13.7	16.7	11.1	152.7	228.4	232.9	227.1	248.4	217.9
20-40 ( $D_2$ )	3.7	6.9	9.3	11.5	12.2	8.7	110.7	130.8	156.5	183.3	165.0	149.3
40-60 ( $D_3$ )	2.6	4.4	6.9	6.5	5.9	5.2	91.0	119.8	134.3	112.7	135.0	118.6
60-80 ( $D_4$ )	1.2	3.0	2.9	3.4	4.1	2.9	65.8	116.2	110.1	94.2	106.3	98.5
>80 ( $D_5$ )	0.6	1.2	1.8	1.9	1.9	1.5	49.33	81.1	90.9	80.9	84.6	77.4
Mean	2.8	4.7	6.4	7.4	8.1		93.9	135.3	144.9	139.6	147.9	
		S.Em.±		CD (P=0.05)				S.Em.±		CD (P=0.05)		
P		0.09		0.25				7.3		20.6		
D		0.09		0.25				7.3		20.6		
PXD		0.20		0.55				16.4		46.0		

$P_0$ : Control.  $P_1$ ,  $P_2$ ,  $P_3$  and  $P_4$ - correspond to periods of spentwash application;  $P_1$ : 5 to 10 years,  $P_2$ : 10 to 15 years,  $P_3$ : 15 to 20 years and  $P_4$ : >20 years  
 $D_1$ ,  $D_2$ ,  $D_3$ ,  $D_4$  and  $D_5$ - correspond to soil depth;  $D_1$ : 0-20 cm,  $D_2$ : 20-40 cm,  $D_3$ : 40-60 cm,  $D_4$ : 60-80 cm and  $D_5$ : >80 cm

**Table-3:** Effect of different periods of spentwash application on soil available phosphorus and potassium

Soil depth (cm)	Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )					Available K <sub>2</sub> O (kg ha <sup>-1</sup> )							
	Control (P <sub>0</sub> )	Periods of spentwash application (years)				Mean	Control (P <sub>0</sub> )	Periods of spentwash application (years)				Mean	
		5-10 (P <sub>1</sub> )	10-15 (P <sub>2</sub> )	15-20 (P <sub>3</sub> )	>20 (P <sub>4</sub> )			5-10 (P <sub>1</sub> )	10-15 (P <sub>2</sub> )	15-20 (P <sub>3</sub> )	>20 (P <sub>4</sub> )		
0-20 (D <sub>1</sub> )	17.43	25.91	31.06	33.02	34.42	28.37	300.20	497.40	615.20	715.0	750.00	575.56	
20-40 (D <sub>2</sub> )	15.43	23.31	27.78	29.18	30.34	25.21	246.40	329.20	546.20	592.0	594.20	461.60	
40-60 (D <sub>3</sub> )	13.44	21.90	24.98	25.15	27.97	22.69	205.80	250.40	397.60	451.8	498.80	360.88	
60-80 (D <sub>4</sub> )	11.28	17.50	22.59	21.09	24.95	19.48	128.20	222.60	312.20	309.8	410.00	276.56	
>80 (D <sub>5</sub> )	10.09	13.30	17.69	17.40	19.20	15.54	122.20	199.60	226.20	226.6	267.60	208.44	
Mean	13.53	20.38	24.82	25.17	27.38		200.56	299.84	419.48	459.0	504.12		
	S.Em.±	CD (P=0.05)			S.Em.±	CD (P=0.05)							
P	0.22	0.61	4.24		11.90								
D	0.22	0.61	4.24		11.90								
PXD	0.48	1.35	9.48		26.62								

P<sub>0</sub>: Control. P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> and P<sub>4</sub>- correspond to periods of spentwash application; P<sub>1</sub>:5 to 10 years, P<sub>2</sub>:10 to 15 years, P<sub>3</sub>: 15 to 20 years and P<sub>4</sub>: >20years. D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub> and D<sub>5</sub>- correspond to soil depth; D<sub>1</sub>: 0-20 cm, D<sub>2</sub>: 20-40 cm, D<sub>3</sub>: 40-60 cm, D<sub>4</sub>: 60-80 cm and D<sub>5</sub>: >80 cm.

**Table-4:** Effect of different periods of spentwash application on soil DTPA extractable zinc and iron

Soil depth (cm)	Zinc (mg kg <sup>-1</sup> )					Iron (mg kg <sup>-1</sup> )							
	Control (P <sub>0</sub> )	Periods of spentwash application (years)				Mean	Control (P <sub>0</sub> )	Periods of spentwash application (years)				Mean	
		5-10 (P <sub>1</sub> )	10-15 (P <sub>2</sub> )	15-20 (P <sub>3</sub> )	>20 (P <sub>4</sub> )			5-10 (P <sub>1</sub> )	10-15 (P <sub>2</sub> )	15-20 (P <sub>3</sub> )	>20 (P <sub>4</sub> )		
0-20 (D <sub>1</sub> )	0.46	1.80	2.02	2.37	2.49	1.83	1.95	5.59	6.06	6.32	7.62	5.51	
20-40 (D <sub>2</sub> )	0.33	1.48	1.51	1.76	1.79	1.37	1.68	5.46	5.63	5.58	5.87	4.84	
40-60 (D <sub>3</sub> )	0.24	0.89	1.00	1.27	1.15	0.91	1.02	5.26	5.59	5.39	5.70	4.59	
60-80 (D <sub>4</sub> )	0.15	0.68	0.86	0.80	0.81	0.66	0.85	5.22	5.15	4.95	5.39	4.31	
>80 (D <sub>5</sub> )	0.11	0.39	0.44	0.40	0.48	0.37	0.38	4.46	4.72	5.03	5.25	3.97	
Mean	0.26	1.05	1.17	1.32	1.34		1.17	5.20	5.43	5.45	5.96		
	S.Em.±	CD (P=0.05)			S.Em.±	CD (P=0.05)							
P	0.03	0.09	0.07		0.20								
D	0.03	0.09	0.07		0.20								
PXD	0.07	0.21	0.16		0.45								

P<sub>0</sub>: Control. P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> and P<sub>4</sub>- correspond to periods of spentwash application; P<sub>1</sub>:5 to 10 years, P<sub>2</sub>:10 to 15 years, P<sub>3</sub>: 15 to 20 years and P<sub>4</sub>: >20years. D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub> and D<sub>5</sub>- correspond to soil depth; D<sub>1</sub>: 0-20 cm, D<sub>2</sub>: 20-40 cm, D<sub>3</sub>: 40-60 cm, D<sub>4</sub>: 60-80 cm and D<sub>5</sub>: >80 cm

**Table-4:** Effect of different periods of spentwash application on soil DTPA extractable manganese and copper

Soil depth (cm)	Manganese (mg kg <sup>-1</sup> )					Copper (mg kg <sup>-1</sup> )							
	Control (P <sub>0</sub> )	Periods of spentwash application (years)				Mean	Control (P <sub>0</sub> )	Periods of spentwash application (years)				Mean	
		5-10 (P <sub>1</sub> )	10-15 (P <sub>2</sub> )	15-20 (P <sub>3</sub> )	>20 (P <sub>4</sub> )			5-10 (P <sub>1</sub> )	10-15 (P <sub>2</sub> )	15-20 (P <sub>3</sub> )	>20 (P <sub>4</sub> )		
0-20 (D <sub>1</sub> )	2.92	5.61	7.01	7.63	8.19	6.27	2.28	4.13	4.97	5.23	5.06	4.34	
20-40 (D <sub>2</sub> )	1.65	3.65	4.53	4.47	4.98	3.86	1.94	3.46	3.19	4.11	4.56	3.45	
40-60 (D <sub>3</sub> )	1.02	2.76	2.94	3.79	4.53	3.01	1.80	2.52	2.12	2.49	2.60	2.30	
60-80 (D <sub>4</sub> )	0.67	2.68	3.02	2.91	4.10	2.68	1.17	1.96	2.52	2.41	2.56	2.13	
>80 (D <sub>5</sub> )	0.22	1.78	2.79	3.11	3.44	2.27	0.73	1.13	1.48	1.77	2.03	1.43	
Mean	1.29	3.30	4.06	4.38	5.05		1.59	2.64	2.86	3.20	3.36		
	S.Em.±	CD (P=0.05)			S.Em.±	CD (P=0.05)							
P	0.20	0.58	0.13		0.35								
D	0.20	0.58	0.13		0.35								
PXD	0.46	1.29	0.28		0.79								

P<sub>0</sub>: Control. P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> and P<sub>4</sub>- correspond to periods of spentwash application; P<sub>1</sub>:5 to 10 years, P<sub>2</sub>:10 to 15 years, P<sub>3</sub>: 15 to 20 years and P<sub>4</sub>: >20year. D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub> and D<sub>5</sub>- correspond to soil depth; D<sub>1</sub>: 0-20 cm, D<sub>2</sub>: 20-40 cm, D<sub>3</sub>: 40-60 cm, D<sub>4</sub>: 60-80 cm and D<sub>5</sub>: >80 cm.

for microorganisms which in turn mineralized the organic forms of phosphorus. Chatterjee *et al.* (2003) and Shinde *et al.* (1993) reported similar findings in this regard. The higher potassium status in progressively spentwash irrigated plots was attributed to the presence of higher amount of potassium (6213.12 mg L<sup>-1</sup>) in the

spentwash. These results were in agreement with the findings of Bose *et al.* (2002).

The DTPA extractable zinc was significantly higher (1.34 mg kg<sup>-1</sup>) in the treatment that received spentwash for >20 years (Table-4). The lowest DTPA extractable zinc (0.26 mg kg<sup>-1</sup>) was

recorded in control. The DTPA extractable zinc was higher at the surface and decreased with depth. Among the depths, the surface depth (0-20 cm) recorded the higher the DTPA extractable zinc ( $1.83 \text{ mg kg}^{-1}$ ) while it remained the at >80 cm depth ( $0.37 \text{ mg kg}^{-1}$ ). Similar trend was observed in respect of DTPA extractable iron. Spentwash irrigation for > 20 years registered  $5.96 \text{ mg kg}^{-1}$  DTPA extractable iron while, control recorded the lowest ( $1.17 \text{ mg kg}^{-1}$ ). The DTPA extractable iron was higher at the surface and significantly decreased with depth. The interaction effect of long-term application of spentwash and soil depths was significant with respect to DTPA extractable iron and zinc.

The mean DTPA extractable manganese and copper contents were higher ( $5.05$  and  $3.36 \text{ mg kg}^{-1}$ , respectively) in plots irrigated with spentwash for > 20 years over rest of the treatments (Table-5). The least values of DTPA extractable manganese and copper were recorded in control ( $1.29$  and  $1.59 \text{ mg kg}^{-1}$ , respectively). Both DTPA extractable manganese and copper were higher at the surface and decreased with depth in all treatments. Among different depths, the 0-20 cm depth recorded higher the DTPA extractable manganese ( $6.27 \text{ mg kg}^{-1}$ ) and lower manganese was observed in > 80 cm depth ( $2.27 \text{ mg kg}^{-1}$ ). Similarly, the surface soil (0-20 cm) recorded higher the DTPA extractable copper ( $4.34 \text{ mg kg}^{-1}$ ) while, lower was observed in > 80 cm depth ( $1.43 \text{ mg kg}^{-1}$ ). The interaction effect was significant between different periods of spentwash application and soil depths in respect of available DTPA extractable manganese and copper. The increased availability zinc, iron, manganese and copper was ascribed to the direct contribution from the effluent as well as by the solubilisation and chelation effect of organic matter. These results are in conformity with the results obtained by Shinde *et al.* (1993) and Sukanya and Meli (2005).

Long-term spentwash irrigation significantly enhanced the organic carbon content, available NPK and micronutrients (Zn, Fe, Mn and Cu) in a Vertisol. The maximum status of organic carbon and available nutrients was observed in the treatment that was irrigated with spentwash for more than 20 years. The nutrient status also marginally improved down the soil depth.

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