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Effect of long-term application of bio-methanated spentwash on sugarcane in Vertisol

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Abstract: A field experiment was conducted at the Ugar Sugar Factory premises, Ugar-Khurd, Athani taluk, Belagavi district to study the effect of different periods of bio-methanated spentwash application on sugarcane crop under Northern Dry Zone (Zone-III) of Karnataka. The crop could not be established in the plot which received spentwash for more than 20 years. Continuous application of spentwash for 5 to 10 years registered significantly higher growth, yield and quality parameters of sugarcane like millable cane height, diameter of cane, number of internodes, intermodal length, number of millable canes, single cane weight, dry matter, yield, brix per cent, pol per cent and purity per cent. Potassium and sodium contents were higher in the treatment that received spentwash for 15 to 20 years while lower potassium and sodium contents were observed in control treatment. The ratio of potassium and sodium was lower in the treatment that received spentwash for 15 to 20 years when compared to other treatments. The uptake of nitrogen, phosphorus and potassium was higher in the treatment that was irrigated with spentwash for 5 to 10 years.

Key wards: Soil salinity, Spentwash, Sugarcane, Vertisol

Introduction

Distilleries are one of the most important agro-based industries in India linked to sugar industry. These produce ethyl alcohol from molasses for potable and industrial uses and generate large volumes of foul smelling dark coloured waste water known as spentwash (SW). For producing one litre of alcohol, 12-15 litres of spentwash is produced. Approximately 40 billion litres of spentwash are generated per annum from 400 distilleries in the country (Rubina, 2013). The spentwash is a concern of environmental pollution owing to its very high organic load. This liquid is dark brown in colour with unacceptable odour and colour. It has higher level of suspended and soluble solids, salts *etc*. The higher soluble solids and salts contribute to higher chemical oxygen demand (COD) (32,800-43,200 mg l^{-1}) and with the presence of higher suspended solids especially organic fractions *etc*. contribute to higher biological oxygen demand (BOD) (12,472- 17,576 mg l^{-1}). Its undesirable properties make the spentwash environmentally un-acceptable for direct disposal. Therefore, distilleries are classified as one of the most (among 14 major) polluting industries as per Central Pollution Control Board (CPCB).

Eco-friendly utilization of distillery effluent in agriculture may serve as one of the nutrient management practices for enhancing crop yields besides reducing the cost involved in fertilizers. But, it has to be used judiciously and cautiously on a limited scale, because of very high organic and chemical load. In order to reduce its high biochemical oxygen demand and chemical oxygen demand, it is passed through bio-methanation digesters and the effluent thus obtained is known as post-methanation effluent (PME) which can be safely used for irrigation with proper dilution. But it is not the case for raw spentwash, which cannot be used continuously. Recent research results suggested that one time application of spentwash is safe and eco-friendly (Selvakumar, 2006). However, due to limited capacity to store this liquid in lagoons for bio methanation, most of the sugar industries resort to illegal disposal of distillery spentwash in the nearest possible location. When the applications are repeated in the small area, it leads to salinization of land and surface and ground water contamination. The recommendation of one time application is not being monitored strictly resulting in land degradation.

Material and methods

The experiment was conducted at the Ugar Sugar Factory premises, Ugar-Khurd, Athani taluk, Belagavi district, to know the effect of different periods of biomethanated spentwash application on sugarcane (Co-86032) crop. The boimethanated spentwash was used as irrigation source (with dilution of 1:10) to sugarcane @ 100 m^3 ha^{-1} $year^{-1}$ (*i.e*., 1 lakh l ha^{-1} yr^{-1}). The soil type of the experimental site was medium calcareous Vertisol. The soil was alkaline in nature with pH ranging from 7.84 to 8.11. The electrical conductivity was higher in spentwash irrigated plots (4.46 dS m^{-1}) compared to control treatment (0.45 dS m^{-1}). The soil organic carbon in the surface layer ranged from 6.0 to 16.7 g kg^{-1}. The available N, P, K and micronutrients were higher in the spentwash applied treatments. The experiment consisted of five treatments laid out in randomized complete block design with five replications. The treatments included P_0- Control, P_1- Application of bio-methanated spentwash for 5-10 years, P_2- Application of bio-methanated spentwash for 10-15 years, P_3- Application of bio-methanated spentwash for 15-20 years, and P_4- Application of bio-methanated spentwash for >20 years. Four budded sets were used for planting of sugarcane and followed wet method of planting. Sets were planted in furrows of 90 cm apart in ridges and furrow method. The sets were planted by pressing in the furrows by letting the water into furrows. Nitrogen, phosphorus and potassium fertilizers were applied @ 240:75:190 kg ha^{-1} of N, P_2O_5 and K_2O in the form of urea, diammonium phosphate and muriate of potash, respectively. And FYM was applied @ 20 t ha^{-1}. The harvested canes were detrashed, bundled and weighed to evaluate the effect of different periods of spentwash application on sugarcane.

Results and discussion

The data (Table 1) indicated that cane height at harvest was significantly influenced by different periods of spentwash application. At harvest, the highest cane height (193.6 cm), diameter of cane (2.90 cm) and number of average internodes (22.32 $plant^{-1}$) was recorded in the treatment that was applied with spentwash for 5 to 10 years as compared all the treatments. The long-term application of spentwash for a period of 15 to 20 years resulted in lower cane height (164.1 cm), cane diameter (2.29 cm) and number of average internodes (17.89 $plant^{-1}$).

The data on internodal length, number of millable canes and single cane weight as influenced by different periods of spentwash application significantly influenced by long-term spentwash application (Table 1). At harvest, the highest internodal length (11.41 cm), number of millable canes (114.12 x 10^3) and single cane weight (1.18 kg $plant^{-1}$) was recorded in the treatment that was applied with spentwash for 5 to 10 years. However, these parameters remained on par with the control treatment *i.e.*, internodal length (10.98 cm), number of millable canes (111.80 x 10^3) and single cane weight (1.11 kg $plant^{-1}$).

At harvest stage; millable cane height, number of internodes, diameter of cane, internodal length, number of millable canes per ha, single cane weight and dry matter accumulation were significantly higher in the treatment that received spentwash for 5 to 10 years compared to all the other treatments. Further, with increased periods of spentwash there was decrease in growth attributing parameters. It clearly indicated that application of spentwash for more than 10 years was detrimental for crop growth. This might be due to phytotoxicity of the effluent, high BOD and COD value which limits the availability of oxygen to crop affecting the growth at higher level and at the same time high ionic concentration causing higher osmotic pressure limiting the water availability to crop (Devarajan *et al*., 1993). Spentwash application to soil at low concentration was reported beneficial and increased sugar cane growth attributing parameters (Haroon and Bose, 2004). Mahimairaja and Bolan (2004) concluded that non-judicious use of spentwash adversely affected crop growth and soil properties by increasing soil salinity. Salinity causes reduction in leaf area as well as the rate of photosynthesis, which together result in reduced crop growth parameters. Also, high concentration of salt was reported to slow down or stop root elongation and reduction in root production.

Cane yield of sugarcane at harvest was significantly influenced by application of spentwash for different periods of time. The treatment which received spentwash for 5 to 10 years recorded significantly higher cane yield (135.1 t ha^{-1}) and total dry matter yield (279.2 g $plant^{-1}$) compared to all other treatments. Application of spentwash for 15 to 20 years registered the lowest cane yield per hectare (83.32 t ha^{-1}) and per plant (212.5 g $plant^{-1}$). In the initial years, the beneficial use of spentwash to the sugarcane was due to its nutritive and growth promoting effect. However, long-term use of spentwash not only polluted the environment but also resulted in the accumulation of salts in the root zone. Soil saturated extract (ECe) conductivities greater than 1.7 dS m^{-1} was reported to decrease yield (Mass and Hoffman, 1977). Salinity reduced plant growth and yield through its osmotic effect (causing water deficit), toxic effect of ions and imbalance of the uptake of essential nutrients. These modes of action may operate on the cellular level and influence all the aspects of plant metabolism (Kramer, 1983).

The brix (21.12 %), pol (19.45 %), and purity per cent (92.16 %), were significantly higher in the treatment that received spentwash for 5 to 10 years as compared to all other treatments (Table 2). Further, with increased periods spentwash application for more than 10 years there was decrease in sugarcane quality parameters. Singh *et al.* (2007) recorded increased brix and pol per cent of sugarcane juice upto 25 per cent concentration of distillery effluent (25% dilution) and above which *i.e.*, 50 and 100 per cent, adverse effect was observed. Sucrose concentration generally decreased with increased salinity, especially in plants grown at 2.93 and 4.70 dS m^{-1} as reported by Tanimoto (1969). Lingle *et al.* (1994) reported that sugarcane was mildly affected by salinity of 1.25 dS m^{-1} and salinities greater than this substantially decreased juice quality parameters (brix, pol and purity %). The reduction in juice quality with increased salinity was due to both decrease in sucrose and increase in minerals. Reduction in the sucrose content was due to inhibitory effect of NaCl on the activity of key enzyme, invertase which is known to play an important role in the synthesis of sugars (Wahid *et al.*, 1997). The long-term application of spentwash for 15 to 20 years recorded the least brix (19.51%), pol (17.51%) and purity (17.51%) per cent compared to all the treatments.

The significant effect of long-term application of spentwash was noticed with respect to sodium content in juice (Table 2).

Table 1. Effect of different periods of spentwash application on growth and yield parameters of sugarcane at harvest

Treatments	Millable cane height (cm)	Diameter of cane (cm)	No. of internodes $plant^{-1}$	Internode length (cm)	No. of millable Canes ('000 ha^{-1})	Single cane weight (kg $cane^{-1}$)
P_0	182.9	2.71	21.26	10.98	111.80	1.11
P_1	193.6	2.90	22.32	11.41	114.12	1.18
P_2	176.3	2.62	19.51	9.65	105.50	1.03
P_3	164.1	2.29	17.89	8.62	93.04	0.90
S.Em.±	2.5	0.04	0.32	0.24	1.53	0.03
C.D. (P=0.05)	7.65	0.13	0.99	0.76	4.73	0.07

P_0- Control; P_1-5 to 10 years, P_2-10 to 15 years and P_3- 15 to 20 years (P_1, P_2 and P_3- correspond to periods of spentwash application)

Table 2. Effect of different periods of spentwash application on yield, total dry matter, yield and quality parameters of sugarcane at harvest

Treatments	Cane yield ($t\ ha^{-1}$)	Total dry matter yield* ($g\ plant^{-1}$)	Cane quality			
			Brix (%)	Pol (%)	Purity (%)	Juice Na ($mmol\ l^{-1}$)
P_0	123.8	270.1	20.26	17.86	88.17	1.04
P_1	135.1	279.2	21.12	19.45	92.16	1.09
P_2	109.3	237.4	20.38	17.98	88.24	1.56
P_3	83.3	212.5	19.51	17.51	89.78	1.74
S.Em.±	3.00	2.8	0.19	0.15	0.92	0.12
C.D. (P=0.05)	9.2	8.5	0.59	0.46	2.84	0.36

* leaves+stem

P_0- Control; P_1-5 to 10 years, P_2-10 to 15 years and P_3- 15 to 20 years (P_1, P_2 and P_3- correspond to periods of spentwash application)

At harvest, the highest sodium content (1.74 mmol l^{-1}) was recorded in the treatment that received spentwash for 15 to 20 years. However, it remained on par with T_2 (10 to 15 years of spentwash application) (1.56 mmol l^{-1}). The crop raised without spentwash (control) recorded the lowest sodium content in juice (1.04 mmol l^{-1}). The long-term use of spentwash polluted the soil environment and resulted in the accumulation of sodium in the soil which favoured higher uptake of sodium by sugarcane. Bernstein *et al.* (1966) examined the cat ion concentration of sugarcane juice grown at different salinities and reported that the potassium concentration in juice did not increase much, but sodium concentration increased more with increased salinity.

Nitrogen content (0.92%) was the highest in the treatment that received spentwash application for 5 to 10 years when compared to other treatments and the lowest nitrogen content (0.68%) was observed in control treatment. The long-term application (>10 years) of spentwash decreased the nitrogen content in sugarcane crop (Table 3). Salinity has a negative interference on the nitrogen acquisition and its utilization by plants as reported by Lewis (1986). The higher phosphorus content (0.18%) was noticed in the treatment that received spentwash application for 15 to 20 years when compared to all other treatments. The lower the phosphorus content (0.13%) was noticed in control treatment. The increased phosphorus content with increased salinity was due to the synergistic effect of sodium as reported by Tuban *et al.* (2010). The potassium (0.95%) and sodium contents (0.35%) were higher in the treatment that received spentwash application for 15 to 20 years when compared other treatments and lower potassium (0.60%) and sodium contents (0.12%) were observed in control treatment. A significant increase in potassium and sodium content was observed in sugarcane with increasing soil salinity. The ratio of potassium and sodium (2.76) was lower in the treatment that received spentwash for 15 to 20 years when compared to other treatments. The higher ratio of potassium and sodium (5.39) was noticed in control treatment.

Uptake of nitrogen (295.8 kg ha^{-1}) was the highest in the treatment that received spentwash for 5 to 10 years compared to other treatments (Table 4). Patil *et al.* (2000) noticed a significant increase in the N uptake (3.24 g pot^{-1}) by the addition of spentwash at 50 $m^3\ ha^{-1}$ over control (0.29 g pot^{-1}). Application of spentwash for more than 10 years decreased nitrogen uptake by sugarcane mainly due to increased salinity and decreased dry matter production. Spentwash contains higher amounts of chlorine which might have suppressed the uptake of N in the form of nitrate and reduced the N content in the crop. This coupled with lower dry matter production decreased N uptake with increased periods of spentwash application (Gahlot *et al.*, 2011). Further, Excessive Na concentration in the plant tissue hinders nutrient uptake, osmotic regulation and causes specific ion toxicity (Arzani, 2008). Similarly, Accumulation of Cl in the root tissue is reported to disrupt membrane's uptake mechanisms and this resulted in increased translocation of Cl to the shoots as reported by Yousif *et al.* (1972). Application of spentwash to the sugarcane crop in smaller quantity and limited periods (<10 years) lead to increase in uptake of nitrogen. The long-term application of spentwash for 15 to 20 years recorded the lowest nitrogen uptake by sugarcane (172.4 kg ha^{-1}) crop at harvest.

Uptake of phosphorus (43.04 kg ha^{-1}) was highest in the treatment that received spentwash application for 5 to 10 years compared to other treatments. However, the extended periods (>10 years) of spentwash application resulted in reduced uptake mainly due to increased salinity and decreased dry matter production. Patil *et al.* (2000) noticed a significant increase in P uptake (2.18 g pot^{-1}) by the application of spentwash @

Table 3. Effect of different periods of spentwash application on N, P, K content and K/Na ratio of sugarcane at harvest (Whole plant)

Treatments	N (%)	P (%)	K (%)	Na (%)	K/Na ratio
P_0	0.68	0.13	0.60	0.12	5.39
P_1	0.92	0.14	0.86	0.18	4.79
P_2	0.81	0.16	0.94	0.24	4.07
P_3	0.86	0.18	0.95	0.35	2.76
S.Em.±	0.026	0.014	0.044	0.01	0.32
C.D. (P=0.05)	0.081	0.042	0.135	0.04	0.99

Table 4. Effect of different periods of spentwash application on uptake of N, P, K and Na in sugarcane at harvest

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Na uptake (kg ha^{-1})
P_0	206.7	39.3	178.3	38.2
P_1	295.8	43.0	276.6	59.2
P_2	204.0	39.9	234.9	61.0
P_3	172.4	36.9	189.5	70.5
S.Em.±	6.70	1.50	5.79	2.30
C.D. (P=0.05)	20.7	3.6	17.9	7.09

P_0- Control; P_1-5 to 10 years, P_2-10 to 15 years and P_3- 15 to 20 years (P_1, P_2 and P_3- correspond to periods of spentwash application)

50 m^3 ha^{-1} over control (0.66 g pot^{-1}). Gahlot *et al.* (2011) concluded that with an increase in the concentration of spentwash, there was decrease in the N and P uptake, when plants were irrigated with higher levels of digested spentwash. The long-term application of spentwash for 15 to 20 years recorded the lower uptake of phosphorus (36.96 kg ha^{-1}).

The long-term application of spentwash for 5 to 10 years showed higher uptake of potassium (276.6 kg ha^{-1}) and higher the uptake of sodium (70.5 kg ha^{-1}) was recorded in 15 to 20 years of spentwash irrigated plot. Spentwash being a rich source of potassium and sodium (6213.12 and 234 mg l^{-1}) contributed to their increased availability in the soil due to long-term application of spentwash. The uptake of N, P, K and micronutrients such as Fe, Mn, Zn and Cu were increased in sugarcane due to the application of spentwash in smaller quantity and shorter period of time as reported by Gopal *et al.* (2001). Akhtar *et al.* (2003) concluded that the main reason for inhibition of growth of sugarcane by salinity was due to competition between sodium ions to the other ions. At low concentrations, sodium might really increase potassium intake, but at high concentrations it reduced the absorption of potassium and increased the sodium content in plant. The lower the uptake of potassium (178.3 kg ha^{-1}).and sodium (38.2 kg ha^{-1}) was observed in control treatment.

The application of spentwash for limited period (5 to 10 years *i.e.*, 5 to10 lakh l ha^{-1} yr^{-1}) increased the growth, yield, quality and nutrient uptake by sugarcane. However, extended use of spentwash for more than 10 years resulted in the accumulation of salts in the root zone adversely affecting the growth, yield and quality of sugarcane. The crop could not be established in the plot which received spentwash for more than 20 years. The brix, pol and purity percent were significantly higher in the treatment that received spentwash for 5 to 10 years as compared to all other treatments. The K/Na ratio decreased with increase in salinity due to increased periods of long-term spentwash application to sugarcane.

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