Biodegradation (2012) 23:897–905
DOI 10.1007/s10532-012-9582-5

ORIGINAL PAPER

Utilization of molasses based distillery effluent for fertigation of sugarcane

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Received: 10 April 2012 / Accepted: 26 July 2012 / Published online: 11 August 2012
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Abstract A field study was carried out to monitor the effect of application of molasses based distillery effluent on yields of sugarcane and soil properties. The treatments consisted of main plots: control (I0), first pre-sowing irrigation with undiluted effluent (I1), one irrigation with effluent: tube-well water (1:3) at tillering stage (I2), two irrigations with effluent: tube-well water (1:4) at tillering and 30 d after tillering stage (I3). The subplots either received no fertilizer application (F0) or had 50 % of recommended dose (50 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} as basal dose (F1) with top dressing of 50 kg N ha^{-1} at tillering and in June before the onset of monsoon. Nitrogen to the ratoon crops was applied in three equal splits. Application of 50 % recommended fertilizer dose increased the cumulative cane yields under different effluent treatments. Use of distillery effluent irrespective of the method of application significantly increased the cumulative yields of sugarcane over no application of effluent significantly at $p \leq 0.05$. After the harvest of second ratoon crop, no significant effect of different treatments was noted on soil pH, electrical conductance and exchangeable Na. Significantly higher build-up of organic C in surface soil was noted under I2 treatment in comparison to I0 treatment at $p \leq 0.05$. With no fertilizer application, both I1 and I2 significantly increased accumulation of alkaline $KMnO_4$ hydrolysable N in 30–45 cm layer in comparison to I0F0 at $p \leq 0.05$. In comparison to I0, use of I2 increased the content of Olsen's P significantly ($p \leq 0.05$) in 30–45 and 45–60 cm layers while I3 increased it significantly at $p \leq 0.05$ in 0–15 and 45–60 cm layers. Use of distillery effluent as pre-sowing or standing crop irrigation increased ammonium acetate extractable K in surface and sub-surface layers significantly in comparison to I0 at $p \leq 0.05$. Thus, use of distillery effluent in sugarcane crop as pre-sown or standing crop irrigation had no adverse impact on soil reaction or electrical conductivity and could save at least fifty percent of basal NPK application with significantly higher cumulative millable cane yields of main crop and two subsequent ratoons.

Keywords Molasses based distillery effluent · Fertigation · Sugarcane · Soil fertility

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Introduction

Molasses, a by-product of sugarcane industry is used to make ethanol. Approximately 3–10 L of molasses is used in producing a litre of alcohol (Joshi et al. 1996). The alcohol distilleries are extensively growing due to widespread industrial usages of alcohol such as in pharmaceuticals, food, perfumery, alternate fuel etc. while with around 319 distilleries producing over 3 gigalitres of alcohol, 40 gigalitres of wastewater is generated each year in India (Uppal 2004). The wastewater generated from distillation of fermented mash has deep brown in color, acidic (3.5–4.5 pH) in reaction, high concentration of organic materials and solids. It is a very complex, caramelized and cumbersome agro-industrial waste. The wastewater generated popularly known as 'Spentwash' has very high biological oxygen demand (BOD) and chemical oxygen demand (COD), with rich content of N, P, K, Ca, S, micronutrients and organic matter. It cannot be directly disposed-off in water bodies for the fear of being hazardous to the environment.

The pollution load of the distillery effluent depends on the quality of molasses, unit operations for processing of molasses and process recovery of alcohols (Pandey et al. 2003). The Ministry of Environment and Forests, Government of India, has declared alcohol distilleries at the top in the "Red Category" industries (Tewari et al. 2007). As per the government policies on pollution control becoming more and more stringent, distillery industries have been forced to adopt far more effective treatment technologies such as aerobic composting, reboiling, biomethanation, mist evaporation, multistage evaporation and reverse osmosis. Such technologies would be beneficial to environment and also be cost effective. In 2003, Central Pollution Control Board, India stipulated that, distilleries should achieve zero discharge in inland surface water courses by the end of 2005 (Pandey et al. 2003). Consequently, the wastewater needs to undergo extensive treatment in order to meet the stipulated environmental demands.

High COD, total nitrogen and total phosphate content of the effluent could cause eutrophication, if disposed to natural water bodies (Kumar et al. 1997) and may endanger aquatic life. Direct disposal of distillery spent wash on land could also be equally hazardous to the vegetation. It is reported to reduce soil alkalinity and manganese availability, thus inhibiting seed germination (Kumar et al. 1997). Distillery effluent after anaerobic treatment still contains considerable plant nutrients in terms of potassium, sulphur, nitrogen and phosphorus besides secondary and micronutrients (Joshi 1999) which are useful to crops and could also partly substitute fertilizer requirement of crops. Therefore, a controlled/diluted application of spentwash on agricultural lands could be a suitable option for the maintenance of soil fertility (Suganya and Rajannan, 2009) and good crop yields. Various researchers have reported that irrigation with distillery effluent increased crop yields, dry matter production, leaf area and, total chlorophyll content, etc. (Pathak et al. 1999; Ramana et al. 2002; Mahimairaja and Bolan 2004). Most of these studies are limited to a single or two crops only in a year. The long-term impact of irrigation usage of distillery effluents on crop yields and soil properties, especially; soil reaction and extent of accumulation of soluble salts in different soil layers need to be ascertained in a given agro-climatic zone before it could be adopted as a farmer's practice. In the region of experimentation (North western part of India) progressive farmers are aware of the fertilizer value of distillery effluent and they utilize it either as pre-sowing application of undiluted distillery effluent (5 cm irrigation) once in a year before plowing and give one to two months time for it's natural decomposition before planting or sowing of crop begins or use two to three irrigations (5 cm) of diluted distillery effluent in the standing crop. With both the cases subsequent irrigations required by the crop are given by tube well water.

The present investigation was carried out to monitor the effect of pre-sown and standing crop application of distillery effluent vis-á-vis fertilizer application on yields of sugarcane-ratoon-ratoon system and changes in the soil properties.

Methods

The effluent used in the study was from a molasses based distillery located at Gajraula, Uttar Pradesh, India. It had 8.24 pH, 2,767 µS cm^{-1} electrical conductance at 25 °C, 16,640 mg total solids, 7,313 mg total suspended solids, 9,327 mg total dissolved solids, 3,805 mg BOD, 10,400 mg COD, 59 mg N, 536 mg K and 216 mg Na L^{-1} effluent.

A field experiment was also carried out at Gajraula. The surface (0–15 cm) soil of the experimental site had sandy loam texture, 6.36 pH and 0.109 dS m^{-1} electrical conductivity at 25 °C in 1:2 soil water suspension, 7.1 g organic C kg^{-1} soil, 268 kg alkaline $KMnO_4$ hydrolysable N, 19 kg Olsen's P and 157 kg exchangeable K ha^{-1}.

The treatments consisted of main plots: control (all irrigations with tube-well water) (I0), first pre-sowing irrigation with undiluted effluent and subsequent irrigation with tube-well water (I1), one irrigation with effluent: tube-well water flow rate (1:3) at tillering stage and rest all irrigations with tube-well water (I2), two irrigations with effluent: tube-well water flow rate (1:4) at tillering and 30 d after tillering stage irrigation and rest all irrigations with tube-well water (I3). The subplots either received no fertilizer application (F0) or had 50 % of recommended dose (50 kg N, 26.2 kg P and 33.2 kg K ha^{-1} as basal dose in the form of urea, diammonium phosphate and muriate of potash) (F1) and top dressing of 50 kg N ha^{-1} at tillering and in June before the onset of monsoon). Nitrogen to the ratoon crops was applied in three equal splits, i.e. after the harvesting of the main crop and in April and June. The rational behind using 50 percent of the recommended basal dose of chemical fertilizers in combinations with main plots was that nearly fifty percent of basally applied N was likely to reach the crop through pre-sowing irrigation which was likely to be made available to the crop through mineralization. The treatments were laid in split plot design with three replications. The unit plot size was 8 m × 3 m. A buffer strip of 1 m was provided between the plots.

When the juice taken from the middle portion of the stalks showed on an average hand refractometer reading of 20, the crop was harvested and dried leaves were stripped off from the top most mature internode at which the stalks could break easily. After removal of dried leaves and top most mature internode, the stalks from each plot were tied and weighed to record the yields of millable cane and expressed on per hectare basis. Sucrose (%) in canes of each plot was also estimated using Hornal's dry lead acetate method as outlined by Spencer and Meade (1955). Sucrose percent in juice was calculated from Schmitz's table using corrected brix and pol reading. Soil samples collected at 0–15, 15–30, 30–45 and 45–60 cm after second ratoon were analysed for pH and electrical conductivity at 25 °C in 1:2 soil water suspension, organic C content, alkaline potassium permagnate hydrolysable N, Olsen's P, 1 N ammonium acetate extractable K and Na following the standard methods outlined by Page et al. (1982).

The data were statistically analysed and the significance of variance was examined by 'F' test at 5 percent level of significance following the procedure outlined by Cochran and Cox (1959). Critical difference (C.D.) values were computed at $p \leq 0.05$.

Results and discussion

Sugarcane yields

It is clearly evident from Fig. 1 that irrespective of the basal application of 50 percent of the recommended dose of chemical fertilizers or no fertilizer application one irrigation with 1:3 diluted effluent at tillering (I2) and two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering (I3) increased the millable cane yields for all harvests significantly over all irrigations with tube-well water (I0) at $p \leq 0.05$, however, the millable cane yield harvested for second ratoon under F0–I2 was statistically similar to the yield under F0–I0. Pre-sowing irrigation with undiluted distillery effluent (I1) did not increase the millable cane yields of main crop and second ratoon significantly at $p \leq 0.05$ but responded significantly well for the millable cane yields of first ratoon. Overall, one presowing irrigation with undiluted effluent (I1) and one irrigation with 1:3 diluted effluent at tillering (I2) and two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering (I3) increased the cumulative cane yields significantly by 22, 35 and 34 percent over all irrigation by tube-well water (I0), respectively, however, the differences among effluent treatments were statistically not significant. Suganya and Rajannan (2009) reported that method of application of distillery spentwash (pre-sown or post-sown) had no significant effect on yields of maize. A basal application of 50 percent of the recommended fertilizer which amounted to 25 kg N, 26.2 kg P and 33.2 kg K ha^{-1} brought a significant ($p \leq 0.05$) increase in the cumulative cane yields under all irrigation treatments; the magnitude of increase was 24., 19, 14 and 14 percent over no application of fertilizer under all irrigations with tube-well water (I0), one presowning irrigation with undiluted effluent (I1), one irrigation with 1:3 diluted effluent at tillering stage (I2) and two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering, respectively. Comparatively lesser yield response due to basal application of 50 percent recommended

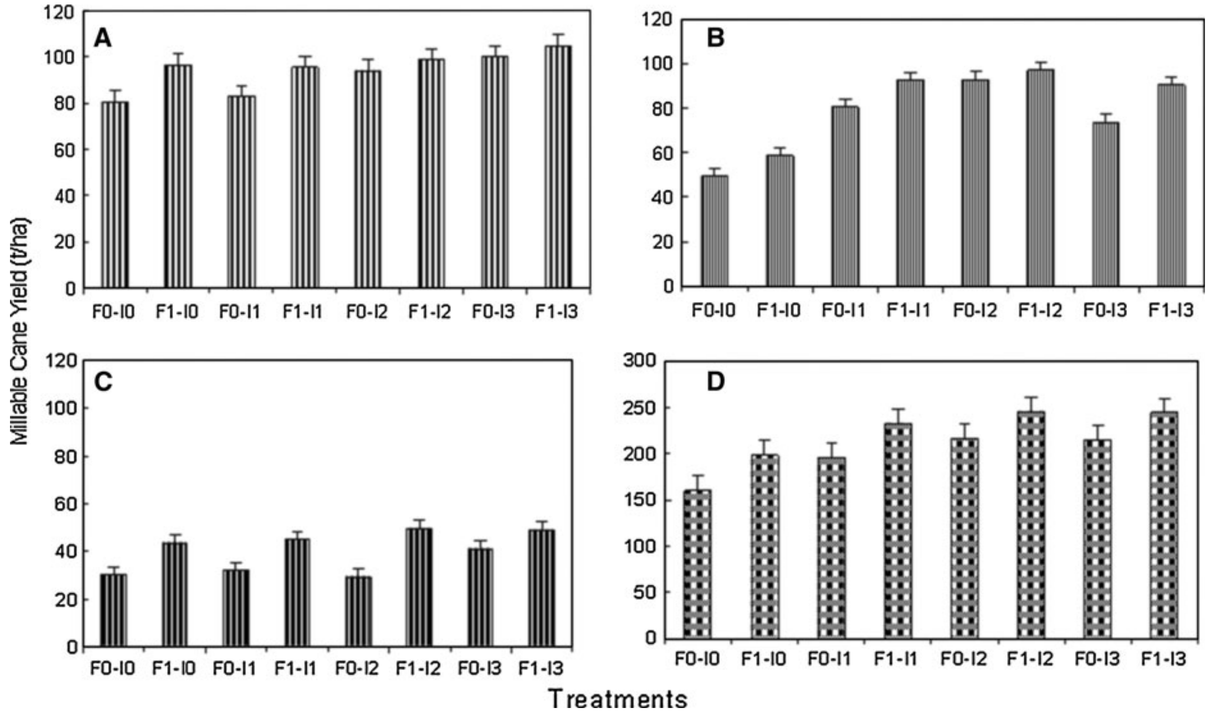

Fig. 1 Effect of interaction of irrigation treatments (I, main plots) and fertilizer application (F, subplot) on millable cane yield (t/ha) of main crop (**a**), first ratoon (**b**), second ratoon (**c**) and cumulative millable cane yields (**d**) ($n = 3$, *vertical bars* indicate critical difference at $p \leq 0.05$)

fertilizer with the use of effluent as presowing or standing crop irrigation in comparison to all irrigations by tube-well water (I0) could be attributed to the 'Law of Dimishing Reurn' as additional nutrients present in the distillery effluent were made available to the crop. Among treatments, the highest cumulative cane yields (245.6 t ha^{-1}) was recorded with one irrigation with 1:3 diluted effluent at tillering along with basal application of 50 percent of recommended fertilizer dose (F1T2). The cumulative cane yield obtained under F1I3 was at par with yields under F1T2.

The effect of different treatments on sucrose (%) of the main as well as first and second ratoons crops was statistically not significant at $p \leq 0.05$ (data not presented). Among the treatments, sucrose (%) in cane ranged from 13.8 to 14.1 percent.

Effect on soil properties

Soil pH

The irrigation treatments as main plots and fertilizer application as sub-plot and their interaction effect failed to influence soil pH significantly at any soil depth (Table 1). In general, soil pH ranges observed in the surface and sub-surface soil after the harvest of second ratoon were 6.23–6.66 for I0, 6.80–7.08 for I1, 6.71–7.08 for I2 and 6.93–7.09 for I3. Subash Chandra Bose et al. (2002) also reported that the soil pH from its initial value with distillery effluent application but the increase in soil pH was statistically not significant even in treatment which received 125 KL^{-1} of distillery effluent ha^{-1}. No significant change in soil pH could be attributed to higher buffering capacity of the soil (Morlat and Chaussod, 2008) and nominal presence of any weak salts namely carbonates or bicarbonates, which on dissolution release free cations, might be the possible causes for the stability of the soil reaction (Hati et al., 2007).

Soil electrical conductivity

Like soil pH, the irrigation treatments as main plots and fertilizer application as sub-plot and their interaction effect also failed to influence soil E.C. significantly at any soil depth (Table 1). Soil E.C. ranges

Table 1 Effect of different fertigation treatments and fertilizer application on soil pH and electrical conductivity at different soil depths after the harvest of second ratoon crop ($n = 3$)

Treatments	Soil pH				Soil EC (dS m^{-1})			
	0–15 cm	15–30 cm	30–45 cm	45–60 cm	0–15 cm	15–30 cm	30–45 cm	45–60 cm
I 0 F 0	6.18	6.56	6.72	6.68	0.22	0.14	0.11	0.11
I 0 F 1	6.28	6.54	6.60	6.61	0.17	0.15	0.12	0.12
I 1 F 0	6.73	6.93	6.95	7.03	0.25	0.20	0.17	0.16
I 1 F 1	6.86	7.04	7.15	7.13	0.27	0.20	0.18	0.20
I 2 F 0	6.84	7.06	7.12	7.06	0.26	0.19	0.23	0.20
I 2 F 1	6.59	6.83	7.03	7.02	0.25	0.18	0.16	0.18
I 3 F 0	7.19	7.14	7.03	6.85	0.24	0.20	0.20	0.18
I 3 F 1	6.90	7.04	7.03	7.01	0.25	0.19	0.16	0.18
Main plot mean								
I 0	6.23	6.55	6.66	6.65	0.19	0.15	0.12	0.12
I 1	6.80	6.99	7.05	7.08	0.26	0.20	0.18	0.18
I 2	6.71	6.95	7.08	7.04	0.26	0.19	0.19	0.19
I 3	7.04	7.09	7.03	6.93	0.24	0.20	0.18	0.18
Subplot mean								
F 0	6.73	6.92	6.96	6.90	0.27	0.18	0.18	0.16
F 1	6.66	6.86	6.95	6.94	0.23	0.18	0.16	0.17
Critical difference ($p \leq 0.05$)								
Main plot (I)	NS	NS	NS	NS	NS	NS	NS	NS
Subplot(F)	NS	NS	NS	NS	NS	NS	NS	NS
F within I	NS	NS	NS	NS	NS	NS	NS	NS
F across I	NS	NS	NS	NS	NS	NS	NS	NS

recorded in the surface and sub-surface layer after the harvest of second ratoon crop were 0.12 to 0.19 dS m^{-1} for I0, 0.18 to 0.26 dS m^{-1} for I1, 0.19 to 0.26 dS m^{-1} for I2 and 0.18 to 0.24 dS m^{-1} for I3. In general, use of distillery effluent for pre-sowing or standing crop irrigation slightly increased the soil E.C. in the surface and sub-surface soil due to the presence of soluble salts but the increase was within safe limits possibly due to regular leaching by subsequent tube-well water irrigation in a well-drained soil. These findings are in corroboration with those of Gopal et al. (2001).

Soil organic carbon

The soil organic C content in the surface (0–15 cm) increased from 3.8 g kg^{-1} soil (I0) to 4.5 to 5.3 g kg^{-1} soil with the use of distillery effluent as pre-sowing or standing crop irrigations; all significant at $p \leq 0.05$ (Table 2). Among main plot treatments, the highest soil organic C content (5.3 g kg^{-1} soil) was recorded under I2. Biswas et al. (2009) also recorded significant increase in soil organic C content in the surface soil due to application of distillery effluent. However, in the present investigation the effect of fertilizer application as sub-plot and interaction effect of irrigation treatments and fertilizer application failed to influence soil organic C content significantly at all soil depths.

Alkaline $KMnO_4$ hydrolysable soil N

In general, use of distillery effluent as irrigation with 1:3 diluted effluent (I2) or two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering (I3) slightly but statistically non-significant decrease in the alkaline KMnO4 hydrolysable N of the surface (0–15 cm) layer as compared to tube-well water irrigation (Table 3). Similarly, I1 and I2 resulted some but statistically non-significant accumulation of alkaline KMnO4 hydrolysable N in 15–30 and 30–45 cm layers. The effect though statistically non-significant could be related to the mobility of

Table 2 Effect of different fertigation treatments and fertilizer application on soil organic carbon (g kg^{-1}) at different soil depths after the harvest of second ratoon crop ($n = 3$)

Treatments	Soil depth			
	0–15 cm	15–30 cm	30–45 cm	45–60 cm
I 0 F 0	3.70	3.30	3.10	2.90
I 0 F 1	3.90	2.20	3.00	1.90
I 1 F 0	4.90	3.50	3.30	3.40
I 1 F 1	4.40	2.60	3.10	2.90
I 2 F 0	5.70	2.30	2.10	2.50
I 2 F 1	4.80	2.60	3.00	3.70
I 3 F 0	4.20	2.80	2.80	4.30
I 3 F 1	4.80	2.80	2.00	2.20
Main Plot Mean				
I 0	3.80	2.80	3.00	2.40
I 1	4.70	3.10	3.20	3.10
I 2	5.30	2.40	2.60	3.10
I 3	4.50	2.80	2.40	3.30
Subplot Mean				
I 0	4.60	3.00	2.80	3.30
F 1	4.50	2.60	2.80	2.70
Critical difference ($p \leq 0.05$)				
Main Plot (I)	0.7	NS	NS	NS
Subplot(F)	NS	NS	NS	NS
F within I	NS	NS	NS	NS
F across I	NS	NS	NS	NS

Table 3 Effect of different fertigation treatments and fertilizer application on soil available N (kg/ha) at different soil depths after the harvest of second ratoon crop ($n = 3$)

Treatments	Soil depth			
	0–15 cm	15–30 cm	30–45 cm	45–60 cm
I 0 F 0	395	295	238	284
I 0 F 1	330	282	347	297
I 1 F 0	343	297	318	293
I 1 F 1	320	309	378	245
I 2 F 0	314	320	345	257
I 2 F 1	293	297	293	270
I 3 F 0	286	230	295	211
I 3 F 1	353	332	307	320
Main Plot Mean				
I 0	363	289	293	291
I 1	331	303	348	269
I 2	303	308	319	263
I 3	320	281	301	266
Subplot Mean				
F 0	335	285	299	261
F 1	324	305	331	283
Critical difference ($p \leq 0.05$)				
Main Plot (I)	NS	NS	NS	NS
Subplot(F)	NS	NS	29	NS
F within I	NS	NS	59	NS
F across I	NS	NS	66	NS

mineralizable organic N to sub-surface layers. Basal application of 50 percent of the recommended dose brought significant ($p \leq 0.05$) increase in the content of alkaline $KMnO_4$ hydrolysable N in sub-soil at 30–45 cm depth. The interaction effect of irrigation x fertilizer application also influenced the content of alkaline $KMnO_4$ hydrolysable N in 30–45 cm layer significantly at $p \leq 0.05$. With no fertilizer application, both I1 (318 kg N ha^{-1}) and I2 (345 kg N ha^{-1}) had significantly higher accumulation of available N as compared to I0 (238 kg N ha^{-1}) in 30–45 cm layer. Though distillery effluent contained only small amount of N in it yet it influenced alkaline KMnO4 hydrolysable N in soil at different depth as noted in the present investigation and the effect could be attributed partly to the direct contribution of N present in distillery effluent and also to the increased microbial activity leading to an increase in hydrolysable N content in soil (Subash Chandra Bose et al., 2002).

Olsen's P

In general, use of distillery effluent as two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering (I3) increased Olsen's P in surface (0–15 cm) and subsurface (45–60 cm) layers significantly as compared to other treatments at $p \leq 0.05$ (Table 4). Irrigation with distillery effluent as one irrigation with 1:3 diluted effluent at tillering (I2) led to a significant increase in the content of Olsen's P in sub-surface layer (30–45 and 45–60 cm) as compared to all irrigation with tube-well water (I0) at $p \leq 0.05$. Pre-sowing irrigation with distillery effluent (I1) increased Olsen's P in 45–60 cm soil layer significantly as compared to I0 at $p \leq 0.05$. An increase in the content of Olsen's P following the application of distillery effluent could be attributed to the presence of P in the effluent as such and also to bicarbonate and organic acids formed during microbial decomposition which

Table 4 Effect of different fertigation treatments and fertilizer application on soil available P (kg/ha) at different soil depths after the harvest of second ratoon crop ($n = 3$)

Treatments	Soil depth			
	0–15 cm	15–30 cm	30–45 cm	45–60 cm
I 0 F 0	16.9	20.3	18.1	12.4
I 0 F 1	17.9	15.6	13.3	8.9
I 1 F 0	10.3	12.7	12.3	19.1
I 1 F 1	12.7	10.3	10.5	6.5
I 2 F 0	14.6	17.0	24.9	17.5
I 2 F 1	21.7	16.6	16.7	13.1
I 3 F 0	29.7	13.1	16.7	14.2
I 3 F 1	28.6	14.1	15.1	13.6
Main Plot Mean				
I 0	17.4	18.0	15.7	10.6
I 1	11.5	11.5	11.4	12.8
I 2	18.1	16.8	20.8	15.3
I 3	29.1	13.6	15.9	13.9
Subplot Mean				
F 0	17.9	15.8	18.0	15.8
F 1	20.2	14.1	13.9	10.5
Critical difference ($p \leq 0.05$)				
Main Plot (I)	2.3	2.2	2.5	2.1
Subplot(F)	NS	NS	2.5	3.6
F within I	NS	NS	NS	NS
F across I	NS	NS	NS	NS

could help in solubilization of native soil P (Subash Chandra Bose et al., 2002). Thus, use of distillery effluent for irrigation in the standing crop offers an alternative way for supplying P to a standing crop and could help in ensuring optimum supply of P to the crops during crop stages at which the P demand of the plant is higher. Basal application of 50 percent of the recommended dose also decreased Olsen's P in the sub-surface (30–45 cm and 45–60 cm) layers significantly as compared to no fertilizer application (F0) at $p \leq 0.05$ owing to immobility of applied fertilizer P to subsoil. The interaction of irrigation treatments x fertilizer applied had no significant effect on the level of Olsen's P in soil at any soil depth.

Ammonium acetate extractable K

In general, use of distillery effluent as pre-sowing irrigation (I1) or irrigation with 1:3 diluted effluent at tillering (I2) or two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering (I3) were conducive to significant accumulation of ammonium acetate extractable K in surface and subsurface layers as compared to irrigation with tube-well water (I0) at $p \leq 0.05$ (Table 5). Joshi et al. (1996) also reported a spectacular increase (88 mg K kg^{-1} soil to 1075 mg K kg^{-1} soil) in the content of available K in surface (0-15 cm) soil following use of distillery effluent in wheat crop. The effect of subplot i.e. no basal application or basal application of 50 percent of the recommended fertilizer dose failed to influence the content of ammonium acetate extractable K significantly ($p \leq 0.05$) at any soil depth The interaction effect of irrigation x fertilizer application also influenced ammonium acetate extractable K significantly at $p \leq 0.05$. With no fertilizer application, significantly higher accumulation of available K was

Table 5 Effect of different fertigation treatments and fertilizer application on soil available K (kg ha^{-1}) at different soil depths after the harvest of second ratoon crop ($n = 3$)

Treatments	Soil depth			
	0–15 cm	15–30 cm	30–45 cm	45–60 cm
I 0 F 0	442	303	384	692
I 0 F 1	461	515	476	661
I 1 F 0	534	707	972	1072
I 1 F 1	738	726	799	1022
I 2 F 0	1456	1199	1195	1172
I 2 F 1	1006	1103	1160	1172
I 3 F 0	910	1153	876	1080
I 3 F 1	830	1064	1406	1179
Main plot mean				
I 0	451	409	430	676
I 1	636	716	886	1047
I 2	1231	1151	1177	1172
I 3	870	1108	1141	1129
Sub plot mean				
F 0	836	840	857	1004
F 1	759	852	960	1008
Critical difference ($p \leq 0.05$)				
Main plot (I)	172	225	343	220
Subplot(F)	NS	NS	NS	NS
F within I	NS	143	240	NS
F across I	459	760	322	NS

recorded in 0–15 cm soil under I2 (1456 kg K ha^{-1}) and I3 (910 kg K ha^{-1}) as compared to I0 (442 kg ha^{-1}) and also in 30-45 cm soil under I1 (972 kg K ha^{-1}), I2 (1195 kg K ha^{-1}) and I3 (876 kg K ha^{-1}) as compared to I0 (384 kg K ha^{-1}); all significant at $p \leq 0.05$. With distillery effluent irrigation, Joshi et al. (1996) also reported increased content of available K in the sub-surface soil. Fertilizer application (F1) brought a significant increase in the content of ammonium acetate extractable K over no fertilizer application (F0) in 15–30 cm soil under treatment receiving all irrigations with tube-well water (I0) signifying restricted mobility of applied K fertilizer and also in 30-45 cm soil layer under under treatment receiving two irrigations with 1:4 diluted effluent at tillering and 30 d after tillering (I3); all significant at $p \leq 0.05$. These observations signify that the use of distillery effluent for irrigation purpose appear to offer a much cheaper option for maintaining K fertility of agricultural lands.

Table 6 Effect of different fertigation treatments and fertilizer application on soil exchangeable Na (m.e. 100 g^{-1}) at different soil depths after the harvest of second ratoon crop ($n = 3$)

Treatments	Soil depth			
	0–15 cm	15–30 cm	30–45 cm	45–60 cm
I 0 F 0	0.13	0.10	0.07	0.14
I 0 F 1	0.19	0.22	0.19	0.18
I 1 F 0	0.16	0.18	0.08	0.08
I 1 F 1	0.12	0.12	0.14	0.14
I 2 F 0	0.16	0.10	0.07	0.05
I 2 F 1	0.15	0.19	0.17	0.15
I 3 F 0	0.19	0.18	0.10	0.07
I 3 F 1	0.18	0.17	0.12	0.08
Main plot mean				
I 0	0.16	0.16	0.13	0.16
I 1	0.14	0.15	0.11	0.11
I 2	0.15	0.15	0.12	0.10
I 3	0.18	0.17	0.11	0.08
Subplot mean				
F 0	0.16	0.14	0.08	0.09
F 1	0.16	0.17	0.15	0.14
Critical difference ($p \leq 0.05$)				
Main plot (I)	NS	NS	NS	NS
Subplot(F)	NS	NS	NS	NS
F within I	NS	NS	NS	NS
F across I	NS	NS	NS	NS

Exchangeable Na

The irrigation treatments as main plots and fertilizer application as sub-plot and their interaction effect failed to influence the content of exchangeable Na significantly at any soil depth after the harvest of second ratoon crop (Table 6). In general, use of distillery effluent as irrigation did not increase exchangeable Na in soil significantly over all irrigations with tube-well water (I0) owing to the usual presence of higher amounts of other cations like Ca^{+2} and Mg^{+2} in the distillery effluent (Subash Chandra Bose et al., 2002) and good drainage condition of soil which did not impede the removal of extra salts including those of Na through drainage water.

Conclusion

Molasses based distillery effluent had favourable effect on cumulative cane yields. Effluent irrigation had potential to cut down the fertilizer consumption of the farmers by fifty per cent. Under good soil drainage conditions, application of distillery effluent as pre-sown irrigation with undiluted effluent (I1) or one irrigation with (1:3) diluted effluent (I2) or two irrigations with (1:4) diluted effluent (I3) helps building up the fertility status of the soil. Since only one fertilizer rate (50 percent of recommended basal dose of NPK fertilizer) against no basal application of fertilizer was tried in the present study, there is a need to conduct more experiments trying more application rates of chemical fertilizers and distillery effluent in future.

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