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Assessing the yield and juice quality of sugarcane under agro-cycling of paper mill solid wastes and treated effluent irrigation

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ABSTRACT

The paper mills are generating appreciable quantities of solid wastes and effluent. The scientific ways and means of recycling in an integrated, eco-friendly manner these solid wastes and effluent for agricultural purposes had been the main objective of this present investigation. The field experiment with sugarcane as test crop utilizing both well water and effluent as sources of irrigation and solid wastes as amendments revealed that effluent irrigation increased the cane yield by 5.78% over well water irrigation. The number of millable canes was 5.53% higher under effluent irrigation than well water irrigation. . The effluent irrigation coupled with Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK increased the yield of canes by 30.9% compared to 100% NPK under well water irrigation. The sugarcane juice analysis revealed that effluent irrigation improved the quality.

Key words: *Effluent, Amendments, Flyash, Biosludge.*

Introduction

The pulp and paper industry is one of the largest consumers of water. Nearly 80% of fresh water used in the pulp and paper mill is discharged as effluent containing organic and inorganic pollutants requiring treatment and disposal. The treated paper mill effluent application to lands is considered to be an innovative approach for its disposal. By this, the effluent is not only kept out of the surface waters, but also implies in recycling where pollutant becomes the nutrients for plant growth, thus reducing the pollution problems.

The fly ash, press mud, bio sludge and lime sludge are some of the solid wastes /by products generated from paper mill which have nutrient elements, manurial and ameliorative potentials that can be profitably exploited for sustainable agriculture. Combined use of industrial effluent along with amendments or sludges might provide the soil with enough nutrients with better physical and microbiological environment thus improving the soil fertility (Trivedi and Raj, 1992 and Hameed Sulaiman and Udayasoorian, 1999). The adverse effects of effluent irrigation from paper factory could be alleviated by resorting to the application of N, P and K along with organic and inorganic amendments such as press mud, farmyard manure and gypsum (Pushpavalli, 1990). Hence, detailed investigations were undertaken to assess the efficiency of utilizing paper mill effluent and solid wastes for crop production.

Methodology

The present investigation on the "Agro cycling of solid wastes from the pulp and paper industry under effluent irrigation " was carried out in the Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore and in the farmer's fields at Pappampalayam, Erode. The treated effluent and solid wastes utilized for crop production were obtained from Seshasayee Paper and Board Ltd., Pallipalayam.

The sugarcane variety CO 86032 was used for this study. It is a cross selection between CO 62198 and COC 671. It is a high yielding and high sucrose containing mid late variety with attractive green canopy. The canes are medium thick and reddish pink in color with prominent ivory marks and purple leaf sheath. The variety is resistant to smut disease. It has high potential for tillering and ratoonability with mean sugar yield of 14.7 t ha^{-1} (SBI, 1993).

Experimental details

The field experiment was laid out in split plot design with three replications.

1. Main plot treatments – Irrigation sources

I_1 – Well water irrigation
I_2 – Treated effluent irrigation

2. Subplot treatments – Solid wastes

T_1 – Control (100% NPK)
T_2 – Biosludge @ 12.5 t ha^{-1} 75% NPK
T_3 – Pressmud @ 12.5 t ha^{-1} + 75% NPK
T_4 – Flyash @ 20 t ha^{-1} + Biosludge @ 6 t ha^{-1} + 75% NPK

The field was ploughed well and opened into ridges and furrows at a distance of 75 cms Fertilizers and organic manures were applied according to treatment details. N as Urea, P as SSP and K as MOP were applied @ 215: 62:112.5 kg ha^{-1} (100% NPK). The entire quantity of P was applied as basal dose, while N & K applied in 3 equal splits on 45th, 90th and 120th days after planting. Solid wastes were applied as basal dose, before planting as per the treatment details. Healthy two budded setts were planted at the rate of 75000 setts per ha, on 5.3.04. To obtain better germination, setts were planted with the buds on lateral sides. The setts were covered with loose soil for a depth of about 5 cm and then the field was irrigated. Immediately after planting, the first irrigation was given followed by life irrigation on 3rd and 7th day. Then irrigations were given once in 8 to 10 days up to 10 months and thereafter at 10 to 12 days interval up to harvest. Earthing up was done at all 3 times of top dressing (first 2 half earthing up and finally fully earthing up). Hand weeding was done twice on 25th and 45th days after planting. Detrashing was done on 120th and 180th days after planting.The crop was harvested at 12th month after planting, i.e., on 7.3.05. The yield of cane was recorded for each plot.

The following biometric observations were recorded.Germination count was recorded on 45th day after planting from the net plot area and expressed as percentage of germinated buds to total number of setts planted. Total number of tillers (main and side tillers) were counted on the 60, 90 and 120 days and expressed as tiller number per plant. At the time of harvest, fully formed millable canes were counted in each plot and expressed as number of millable canes per plot. Height, weight, girth and number of internodes per millable cane were recorded at harvest from randomly selected five canes from the net plot area and the data was expressed as mean of five canes. Weight of cane harvested from net plot area was recorded and expressed as kg per plot.

The juice samples were collected from 5 canes selected at random per plot at harvest. The following juice quality parameters were determined.

Brix

Brix was determined by using Brix hydrometric spindle. The temperature of the juice was noted and the temperature corrected reading was reported as Brix per cent (Meade and Chen, 1977).

Pol per cent

About 100 mL of juice was clarified using lead sub acetate and filtered. The optical rotation of this clear transparent juice was recorded using polariscope (Meade and Chen, 1977).

Purity coefficient

Purity coefficient was calculated with the help of Brix and Pol per cent of juice as per the formula given below:

$$\text{Purity coefficient} = \frac{\text{Pol per cent}}{\text{Brix per cent}} \times 100$$

Commercial cane sugar per cent (CCS)

The CCS per cent was calculated as per the formula given below (Meade and Chen, 1977).

$$\text{CCS per cent} = \text{Pol} - (\text{Brix} - \text{Pol} \times 0.4) \times 0.75$$

Sugar yield

Sugar yield was calculated as per the following formula and expressed in t ha^{-1}.

CCS (t ha^{-1}) = CCS per cent x cane yield (t ha^{-1}) / 100

Results and Conclusion

Germination percentage

Among the sources of irrigation, I_2 (effluent irrigation) registered significantly higher germination percentage of 71.2% followed by I_1 (well water irrigation) which registered 65.8% of germination. Within the treatments, it was T_4 (Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK), which recorded the highest germination under both the irrigation sources (I_1 T_4 – 73.3%, I_2T_4 – 73.3%). The interaction I_1T_4 and I_2T_4 were on par with each other.

Tillering capacity

The mean number of tillers ranged from 104 to 199.6 per plot. On the 90th day of planting, the number of tillers was maximum invariably in all treatments. Regarding the irrigation treatments, effluent irrigation (I_2) registered higher number of tillers than well water irrigation (I_1).

The maximum number of tillers (199.6) was observed in the treatment receiving Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK (T_4) and irrigated with effluent (I_2) on the 90th day of planting.The minimum number of tillers (104) was observed in the treatment (T_1)applied with 100% NPK under well water irrigation (I_1).

The interaction effect between irrigations and solid waste application was not significant.

Stem girth of millable cane

The stem girth of millable canes at the time of harvest was maximum (10.3 cm) under the treatment I_2T_4 (Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK under effluent irrigation). The plots under effluent irrigation produced millable canes with higher mean stem girth of 9.2 cm than under well water irrigation of 8.8 cm.

Number of nodes

The number of nodes in each millable cane ranged from 19 to 24 at the time of harvest. The maximum number of nodes (22.5) was observed under effluent irrigation (I_2) than under well water irrigation (20.3). Among the solid wastes, T_4 (Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK) recorded maximum number of internodes under both irrigations (I-$_1T_4$ – 21.0, I_2T_4–2.40). The treatment T_3 (press mud 12.5 t ha^{-1} + 75%NPK) performed equally well as that of T_4.

Yield parameters of sugarcane at harvest as influenced by effluent irrigation and solid wastes application at harvest

Treatments	Stem girth (cm)	Number of internodes	Internodal distance (cm)	Number of millable canes	Height of millable canes (cm)	Yield (kg/plot)
I_1 T_1	7.3	19.0	9.3	130.0	225.1	275.0
T_2	8.8	20.0	10.2	165.0	232.5	315.0
T_3	9.2	21.0	11.5	170.0	250.2	318.0
T_4	10.0	21.0	13.4	185.0	258.1	322.0
Mean	8.8	20.3	11.1	162.5	241.5	307.5
I_2 T_1	8.3	20.0	10.5	135.0	238.3	294.0
T_2	9.0	22.0	12.3	168.0	246.8	317.0
T_3	9.3	24.0	14.4	185.0	257.3	330.0
T_4	10.3	24.0	15.3	198.0	265.7	360.0
Mean	9.2	22.5	13.1	171.5	252.0	325.3

	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)
I	0.10	0.41	0.24	1.02	0.13	0.58	1.75	7.52	NS	NS	3.46	14.90
T	0.15	0.33	0.35	0.76	0.20	0.43	2.81	6.13	4.02	8.76	5.26	11.47
I x T	0.21	0.54	0.49	1.31	0.27	0.74	NS	NS	NS	NS	7.32	19.42

I_1 – Well water irrigation
I_2 – Effluent irrigation
T_1 – Control (100% NPK)
T_2 – Bio sludge 12.5 t ha^{-1} + 75% NPK
T_3 – Press mud 12.5 t ha^{-1} + 75% NPK
T_4 – Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK)

Considering the interactions effect between effluent irrigation and solid wastes application, I_2T_4 performed the best and was significantly superior than the rest of the treatments.

Inter nodal distance

The mean inter nodal distance was maximum (13.1 cm) under effluent irrigation (I_2) than under well water irrigation I_1 (11.1 cm). The interaction I_2T_4 registered the highest inter nodal distance of 15.3 cm. The least inter nodal distance of 9.3 cm was observed in the interaction (I_1T_1) under well water irrigation and incorporated with 100% NPK.

Number of millable canes

The count of millable canes per plot at the time of harvest ranged between130 to 198. The highest mean number of millable canes of 198 was registered under effluent irrigation (I_2) and the least 130 under well water irrigation (I_1). Among the treatments, T_4 (Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK) recorded the highest number of millable canes under both irrigations (I_1 –185, I_2 - 198).

The interaction between irrigation sources and solid waste treatments was not significant.

Height of millable canes

The tallness of the millable canes during the harvest ranged from 225 cm to 266 cm.

Effluent irrigation recorded lengthier canes of 252 cm than well water irrigation (242 cm). Among the solid wastes application, T_4 (Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK) recorded the longest millable canes under both irrigations (I_1 –258 cm, I_2 – 266 cm). The interaction effect was not significant.

Yield

The yield of millable canes per plot ranged from 275 kg to 360 kg/plot. Plots under effluent irrigation (I_2) recorded higher mean yield of 325 kg than those under well water irrigation (308 kg).

The plot receiving effluent irrigation and applied with fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK (I_2T_4) recorded the highest yield of 360 kg. The lowest yield of 275 kg / plot was recorded by I_1T_1 receiving well water irrigation and 100% NPK fertilizers.

The effluent irrigation increased the cane yield by 5.78% compared to well water irrigation The number of millable canes was 5.53% higher under effluent irrigation than under well water irrigation which could be due to the favourable influence of the effluent and the ameliorating effect of the amendments on the effluent irrigation.

Among the treatments, the treatment (T_4) which received Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK, under effluent irrigation (I_2) registered the highest yield nearly 30.9 per cent over that of I_1T_1 (receiving 100% NPK under well water irrigation). The increase in yield of millable canes could be due

Sugarcane juice quality parameters as influenced by effluent irrigation and solid wastes application

Treatments	Brix	Pol	Purity	CCS
I_1 T_1	18.26	15.81	85.61	11.20
T_2	18.31	15.83	85.87	11.30
T_3	18.32	15.85	86.52	11.15
T_4	18.36	16.04	86.54	11.33
Mean	18.31	15.88	86.14	11.25
I_2 T_1	18.47	16.65	86.22	11.12
T_2	19.39	16.70	86.38	11.72
T_3	19.62	16.98	86.45	11.94
T_4	19.89	17.05	86.55	11.94
Mean	**19.34**	**16.85**	**86.40**	**11.68**

	SEd	CD(0.05)	SEd	CD(0.05)	SEd	CD(0.05)	SEd	CD(0.05)
I	0.21	0.90	0.18	0.78	NS	NS	NS	NS
T	NS	NS	NS	NS	NS	NS	NS	NS
I xT	NS	NS	NS	NS	NS	NS	NS	NS

I_1 – Well water irrigation
I_2 – Effluent irrigation
T_1 – Control (100% NPK)
T_2 – Bio sludge 12.5 t ha^{-1} + 75% NPK
T_3 – Press mud 12.5 t ha^{-1} + 75% NPK
T_4 – Fly ash 20 t ha^{-1} + Bio sludge 6 t ha^{-1} + 75% NPK)

to the enrichment of soil by the addition of fly ash which contained appreciable amounts of plant nutrients coupled with the nutrient from the combined use of effluent along with amendments which enhanced the soil fertility. The above findings are in line with those of Reddy *et al.* (1981), Pushpavalli (1990) and Hameed Sulaiman and Udayasoorian (1998). Fertilizer being a high-cost input, it has been clearly brought out that with a 25% saving of fertilizer cost, an additional yield increase of 30.9 % could be achieved by the combined incorporation of fly ash and bio sludge. Press mud 12.5 t ha^{-1} + 75% NPK increased cane yield by 20.0% followed by bio sludge + 75% NPK which contributed to 15.3% higher yield than 100% NPK alone, both the treatments also ensured 25% saving in the fertilizer cost.

Similarly, all the yield parameters such as stem girth, number of internodes, height of millable canes, germination and tillering capacity were also higher under effluent irrigation and Fly ash + Bio sludge application followed by press mud and then by bio sludge alone compared to 100% NPK.

Influence of effluent irrigation and solid wastes application on sugarcane juice quality parameters

Brix

Effluent irrigation (I_2) registered the maximum brix per cent of 19.34 per cent followed by 18.31 per cent for well water (I_1) irrigation. The effect of solid waste application treatments on Brix value was not significant.

Pol per cent

The Pol per cent was the highest (16.85 %) under effluent irrigation (I_2) than under well water irrigation I_1 (15.88 %) and both were significantly different from each other. Solid wastes application did not affect the Pol per cent of the juice.

Purity and CCS

Purity and Commercial Cane sugar percentage were not significantly different under various sources of irrigations and solid waste application. The purity and CCS of sugarcane juice under effluent irrigation (I_2) was equally good as that under well water irrigation (I_1).

The sugarcane juice quality parameters such as brix, pol, purity and CCS were significantly high under effluent irrigation compared to fresh water irrigation and solid wastes application did not affect the juice quality parameters The increase in brix, pol, purity and CCS of sugarcane juice were 1.03, 0.97, 0.26, and 0.43 units under effluent irrigation than under well water irrigation. The solid waste incorporation did not affect the juice quality parameters of sugarcane. This was in line with the findings of Francis *et al.* (1999) .

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