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Effect of different levels of distillery effluents on growth, yield and soil health in sugarcane crop in Orissa*

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In India sugarcane is being grown in 4.83 million ha area with very meager productivity of 66.8 tonnes/ha (MOA 2006). In southern and western states its productivity is quite high (63.2 to 100.8 tonnes/ha.) but in eastern states it is very low (39.5 to 66.2 tonnes/ha.) over the national average productivity of 66.8 tonnes/ha. Sugarcane being annual to one-and-half-year duration as well as water- and nutrients-exhaustive crop, depletes water and soil nutrients extensively. Hence, adequate attention for efficient management of water and nutrient is required to keep these resources intact for sustainable development (Suman *et al.* 2006, Keating *et al.*1997). When the sugarcane distillery effluents with rich in plant nutrients are used in crop production in a proper proportion with good quality water, the soil health and crop performance is improved (Rajeshwari *et al.* 2007, Biswas *et al.*2009). Thus, huge amount of inorganic fertilizer is saved as these inorganic inputs are costly and are not being used efficiently in the field (Pathak *et al.* 1999). The distillery effluent also results into increase in soil salinity and groundwater pollution (Joshi *et al.* 2000, Chonkar *et al.* 2000). The efficiency of these inputs is very low in the farmer's field due to inadequate technological knowledge on input management. So to make the best use of distillery effluents of sugar industries, a study was made in light-textured red soil to evaluate response of various levels of distillery effluents on crop growth, quality of juice and sugarcane yield at Sakti Sugar Industries Dhenkanal, Orissa during season of winter (*rabi*) 2006–07.

Distillery effluents of Sakti Sugar Industries, Dhenkanal, Orissa is rich in major and minor plant nutrients (NO_3_N 2 649 ppm, Potassium 121.6 ppm, Calcium 1519 ppm, Magnesium 700 ppm, Sodium 97.8 ppm, total organic carbon 0.87%, total dissolved solids 32 g/litre). If it is used as supplemental irrigation and as nutrient sources instead of draining into drainage channel, substantial amount of inorganic fertilizers is saved and groundwater pollution is minimized as it gives good response without any adverse effect on crop yield and quality of juice.

The field experiment was carried out in Sakti Sugar Industries Ltd, Dhenkanal, Orissa (longitude 85° 36'; latitude 20 °39') during 2006–07 with 'Co 86032' sugarcane as test crop. The experimental field was light textured sandy loam soil with acidic in nature, low organic carbon, medium in available nitrogen, high in available phosphorus and potassium (Table 1). Other major and micro-nutrients are also available in good amount which helps for plant growth. Single eye bud sugarcane set was planted in nursery on 9 December 2005 and it was taken in main field along with

Table 1 Effect of distillery effluents on crop yield and quality of sugarcane

Treatment	Frequency of application	Sugarcane yield (tonnes/ha)	Sugar yield (tonnes/ha)	CCS (%)	Brix (%)	Polarity (%)	Purity (%)
0(control)	Once before planting	50.32	7.11	14.17	20.49	16.34	78.93
20 m^3	Once before planting	94.69	13.88	14.68	21.20	17.13	83.66
40 m^3	Once before planting	104.55	16.77	16.04	22.68	19.46	84.14
60 m^3	Once before planting	83.96	13.17	15.69	22.68	18.25	80.13
80 m^3	Once before planting	79.36	12.53	15.78	22.70	18.97	83.93
CD (*P*=0.05)		15.37	2.11	0.56	0. 41	0.88	0.65
CV(%)		9.86	8.06	1.69	2.06	2.59	0.42

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polyethylene bag with soil and planted in main field on 6 February 2006 in crop geometry of 1.0 m×0.50 m. The treatment comprised five levels of distillery effluents, replicated thrice in randomized block design (Table 1). The distillery effluents were applied @ 0, 20, 40, 60 and 80 m^3/ha well in advance on 20 November 2005 to avoid any injuries to sugarcane plant sampling. It was thoroughly mixed in soil. After planting of sugarcane sets, bore well irrigation water was applied at 30 mm cumulative evapo-transpiration (ET) crop from 28 February 2006. The daily reference ETo was computed by Hargreaves method (Hargraves and Samani 1985) by taking meteorological data from the Sakti Sugar Industries, Dhenkanal. The ET crop was then computed by considering crop co-efficient at different crop growth stages (planting to 29 March = 0.65 kc; 30 March to 29 May = 0.85 kc, 30 May to 27 July = 1.0 kc, 28 July to 25 October = 1.15 kc, 29Oct. to 27 Dec. 0.85 kc; 28 Dec to harvest =0.65 kc). During rainy season no irrigation was applied, however from October 2006, only three irrigations was given as crop requires sufficient amount of water stress for increasing sugar concentration. To assess the treatment effect on sugarcane crop, periodic biometric observations on plant height, leaves, tillers, number of internodes and juice quality, like *p*H electrical conductivity, specific gravity, brix, polarity, purity percentage was monitored. At harvest cane yield, partitioning of shoot, juice and trash was recorded. Based on brix, purity and polarity of the juice, commercial cane sugar (CCS) was computed with the following formulae.

CCS (%) = [Pol (Brix-Pol)*0.45)]*0.75

Sugar yield (tonnes/ha) = CCS% * sugarcane yield (tonnes/ha.)

Application of differential amount of distillery effluents had good response on sugarcane yield and juice quality parameters, however very high amount of distillery effluents in soil adversely affected crop growth and yield. Application 40 m^3/ha distillery effluent gave maximum sugarcane yield of 104.55 tonnes/ha. Further increase in quantity of distillery effluents to 60 m^3 and 80 m^3/ha reduced the sugarcane yield by 19.7% and 24.1%, respectively, over 40 m^3/ha distillery effluents. Hence addition of 40 m^3/ha distillery effluent before planting of sugarcane is recommended to maximize sugarcane yield in light textured upland soil of Orissa where rice (*oryza sativa* L.) is dominated during rainy (*kharif*) season. Similarly in case of sugar yield there was significant improvement with application of 40 m^3/ha distillery effluent. The magnitude of increasing sugar yield at this level was 135.8% higher than fresh water but with further increase in distillery effluent level to 60 m^3 and 80 m^3/ha, reduced the magnitude of increasing sugar yield which was recorded to increase by 85.1% and 76.19% over the fresh water respectively. With respect to commercial cane sugar (%), brix, polarity and purity percentage, application of 40 m^3/ha distillery effluent had more CCS, brix, polarity and purity percentage as compared to other distillery effluent levels tested. Generally, there is progressive decrease of sucrose concentration with increasing nutrient level because of more vegetative growth. In this present experiment, total amount of plant nutrients available in 40 m^3/ha was quite sufficient for optimum plant growth. Beyond this level the plant root might have got damaged due to high amount of ionic concentration in soil profile though the major plant nutrients within crop root zone showed very high concentration in 60 m^3/ha distillery effluent. Deverajan *et al.* (1994) reported that application of post-methanated distillery effluents (PMDE) @ 125 to 250 m^3/ha as liquid manure is very safe in most of the agricultural field crops. However, Chonker *et al.*(2000) have cautioned that one should not use PMDE continuously. It should be discontinued after 1–2 crops to avoid any adverse effect on soil and groundwater quality. It has been observed that excess amount of nitrogen generally increases immature suckers, continues vegetative growth till maturity and binds sugars with nitrogenous compound and then produces undesirable sugar. Wiedenfeld (1995) reported that during ripening phase abundance of nitrogen in plant is detrimental to sucrose accumulation and finally the sugar yield. In the present study low sugar yield beyond 40 m^3/ha distillery effluent could be due to excess amount of plant nutrient in soil at 60 m^3/ha and leaching loss of more plant nutrient due to heavy loads of salts in case of 80 m^3/ha dose. Hence, application of 40 m^3/ha distillery effluent is considered to be optimum dose for sugarcane production.

Response to sugarcane yield was estimated by considering yield as dependent variable(y) and distillery effluent levels as independent variables(x). These parameters were tried in linear, log-linear, exponential and polynomial. Out of these equations, the best fit was found to be third degree polynomial in which maximum R^2 value was obtained. Fig. 1 reveals that increasing distillery effluent level, increased cane yield continuously up to 40 m^3/ha but the magnitude of increasing cane yield was more between 20 and 40 m^3/ha distillery effluent level. Thereafter the reduction in cane yield was very high between 40 and 60 m^3/ha. However between 60 and 80 m^3/ha distillery effluent levels it was not at the same magnitude as it occurred between 40 and 60 m^3/h distillery

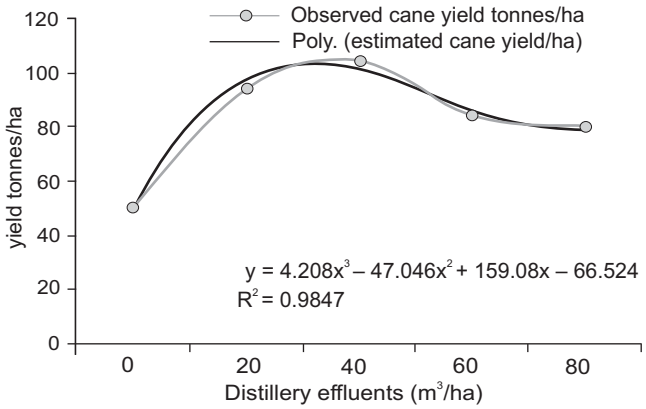


Fig 1 Yield response with different distillery effuents

Table 2 Effect of different levels of distillery on juice quality of sugarcane

Treatment	*p*H	EC (dS/m)	specific gravity ($g/cm^{3)}$
0(control)	5.25	4.55	1.043
20	5.30	5.58	1.061
40	5.32	5.71	1.064
60	5.37	5.90	1.070
80	5.44	6.03	1.078
CD (*P*=0.05)	0.073	0.19	0.017
CV (%)	5.5	13.3	12.4

effluent level. Application of high level of distillery effluent at a time might have moved beyond active crop root zone and not affected active root zone as it was affected in 60 m^3/ha distillery effluent level.

$y = 4.2083x^3 – 47.046x^2 + 159.08x – 66.524$, $R^2 = 0.9847$

y= estimated sugarcane yield (tonnes/ha), x= distillery effluents (m^3/ha)

The quality of juice (*p*H, EC and specific gravity) which was recorded at harvest of crop had highest values in 80 m^3/ha distillery effluent treated plot but the effect was statistically at par between 60 and 80 m^3/ha distillery effluent levels. Application of good quality irrigation water throughout the crop growth period had very low value of all above parameters. This clearly indicates that distillery effluents contributes good amount plant nutrients and improves soil properties (Table 2).

Application of distillery effluent improved chemical properties of the experimental field with respect to all major and micro-nutrients except Zn and Mn, however the magnitude of improvement in soil properties varied due to concentration of distillery effluent applied. In case of *p*H of the soil, it was improved substantially at 20 and 40 m^3/ha distillery effluent level, thereafter the soil *p*H was lowered down with higher amount of distillery effluent application (Table 3). With respect to major plant nutrients, distillery effluent contributed good amount of nitrogen, phosphorus and potassium up to 60 m^3/ha application rate. Beyond this level, reduction in concentration of nitrogen and phosphorus occurred. In case of other major plant nutrients(Ca, Mg, Zn, Cu, Fe, Mn) , the overall ionic concentration was increased from 667.35 mg/kg soil in case of without distillery effluent treated plot to 1352.72 and 1582.75 mg/kg soil in 20 and 40 m^3/ha distillery effluent treated plot, respectively. However in 60 and 80 m^3/ha distillery effluent treated plot, the total ionic concentration was reduced to 1052.49 and 894.72 mg/kg soil respectively. This trend indicates that application of higher dose of distillery effluent, ie beyond 40 m^3/ha had less effect on soil improvement. This could be due to more amount of salt movement beyond root zone having more loads of ingredients in applied distillery effluents. Bose *et al.* (2002) in coastal sandy soil of Tamil Nadu, have found that application of 1.25, 2.5, 3.75, 5.0 and 6.25 lakh l/ha of distillery effluent, mixed 40 days before planting of sugarcane improved soil properties and increased organic carbon, nitrogen, potassium, calcium, magnesium and micro-nutrients progressively over control plot and these nutrients helped for higher crop growth and yield, however 3.75 lakh l/ha distillery effluents recorded highest cane yield. Alternatively the field of sugarcane crop can be improved biologically also by growing intercrop with legumes. Suman *et al.* (2006) reported that growing of greengram, cowpea, lentil, maize, mustard and potato as intercrop increased available nitrogen by 3 to 20% with more in legume and less in non-legume crops than sugarcane alone. So, in case of shallow groundwater-table condition, where distillery effluents contribute and pollute groundwater, then such intercrop systems could be adopted.

The tiller production, functional leaves/plant and plant height were clearly distinguished due to application of differential amount of distillery effluents. During formative stages (first four months after planting) the magnitude of crop growth rate was more in all treatments. Thereafter it was slowed down (Table 4). The plant height at harvest in control was 272 cm. With application of 20, 40 m^3/ha of distillery effluent, the increase in plant height was 8.5 and

Table 3 Important soil properties after harvest of sugarcane under different effluent volumes

Treatment effluent volume (m^3/ha)	*p*H	Organic carbon (%)	Concentration (mg/kg)								
			N	P	K	Ca	Mg	Zn	Cu	Fe	Mn
Initial	5.80	0.56	120.24	22.22	224.65	441.08	44.00	3.52	9.64	19.06	177.60
0	5.59	0.46	133.12	8.37	185.71	512.58	43.80	1.93	2.42	38.52	68.10
20	6.98	0.46	136.15	17.8	264.53	1025.17	240.90	1.84	3.58	23.48	57.48
40	6.44	0.46	154.06	19.13	285.41	695.65	306.60	2.73	4.63	35.54	79.00
60	6.02	0.43	259.34	26.78	208.83	659.03	287.60	0.99	2.67	33.56	68.64
80	5.94	0.51	155.78	16.93	292.37	475.97	262.80	2.36	3.53	47.86	102.20
SE	0.21	0.02	20.65	2.51	17.78	88.39	48.54	0.35	1.09	4.25	18.17
SD	0.50	0.05	50.58	6.14	43.55	216.50	118.91	0.86	2.68	10.42	44.52

Table 4 Effect of distillery effluents on growth of sugarcane

Treatment						*Height (cm)*						
	1.4.06	17.4.06	4.5.06	17.5.06	18.6.06	19.7.06	19.8.06	19.9.06	19.10.06	19.11.06	19.12.06	15.1.07
control	33.3	39.3	54.0	71.3	120.0	190.0	213.0	223.0	239.3	252.7	264.3	272.3
20 m^3/ha	42.0	66.0	86.0	114.0	160.0	231.7	254.0	267.3	276.0	283.7	289.7	295.0
40 m^3/ha	44.0	67.0	88.3	116.0	158.7	237.7	257.0	270.0	279.3	289.0	296.3	305.3
60 m^3/ha	39.0	49.3	62.7	78.3	125.0	187.3	218.7	236.3	254.7	272.0	289.7	302.3
80 m^3/ha	36.7	45.0	59.3	79.3	118.3	173.3	214.3	230.0	242.0	256.3	271.0	284.3
CD (*P*=0.05)	9.49	22.63	31.96	40.90	42.82	67.11	47.27	46.70	39.35	35.14	35.61	37.97
						Tillers/hill						
	1.4.06	17.4.06	4.5.06	17.5.06	18.6.06	19.7.06	19.8.06	19.9.06	19.10.06	19.11.06	19.12.06	15.1.07
control	3.3	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	4.0	4.0	4.0
20 m^3/ha	4.3	4.3	4.7	4.7	4.7	5.0	5.7	5.7	5.7	6.0	6.0	6.0
40 m^3/ha	4.7	5.0	5.3	5.3	5.3	5.7	5.7	6.0	6.0	6.0	6.0	6.0
60 m^3/ha	4.3	5.0	5.0	5.0	5.7	5.7	5.7	5.3	5.7	5.7	5.7	5.7
80 m^3/ha	2.3	2.7	3.0	3.0	3.0	3.7	4.3	4.7	4.7	4.7	4.7	4.7
CD (*P*=0.05)	1.86	2.12	1.97	2.05	2.35	1.97	1.78	1.78	1.86	1.78	1.63	1.63
						Leaves/plant						
	1.4.06	17.4.06	4.5.06	17.5.06	18.6.06	19.7.06	19.8.06	19.9.06	19.10.06	19.11.06	19.12.06	15.1.07
control	8.7	9.3	10.0	11.0	9.7	8.3	8.0	7.7	7.3	7.3	7.3	7.3
20 m^3/ha	9.0	9.7	10.7	11.7	10.7	9.7	9.3	9.3	10.0	9.7	9.7	8.7
40 m^3/ha	9.0	9.7	10.7	11.7	10.7	9.7	9.3	9.3	10.0	9.7	9.7	8.7
60 m^3/ha	8.7	8.6	9.6	10.9	10.6	10.2	10.1	9.1	9.3	9.2	8.6	7.9
80 m^3/ha	8.0	8.0	9.0	9.3	9.3	9.3	9.0	8.3	8.3	8.3	8.0	8.0
CD (*P*=0.05)	1.47	2.46	1.69	2.33	1.66	1.39	1.92	2.14	2.54	2.24	2.31	2.31

12.1% respectively. However, further increasing distillery effluent to 60 and 80 m^3/ha, increased plant height with lesser magnitude. The tiller production in 80 m^3/ha distillery effluent treated plot was quite slow at the beginning and slow production of tillers continued even up to harvest of the crop as high concentration of chemical ingredients in this plot might have restricted tiller production. Number of leaves also depends on total number of inter-nodes in plants. As plant height was not progressively increased with higher amount of distillery effluent application, the number of leaves/plant was also not increased at same magnitude. The older leaves were continuously removed after May 2006 and functional leaves were retained intact. This process was continued up to December 2006.

To evaluate whether the crop contains sufficient amount of sucrose/solid in the juice or not the whole sugarcane plant was taken to monitor *in-situ* brix value at 5, 10, 15, 20, 25 and 30 inter node on 4 January 2007. Fig 2 shows that on an average of 6 observations in a single plant, the brix value of 24.0, 25.3, 26.05, 25.0 and 25.5% was recorded in fresh water, 20, 40, 60 and 80 m^3/ha distillery effluent treated plots, respectively. The crop irrigated with fresh water had low brix percentage than other treatments in which differential amount of distillery effluent was added. Similarly, at five inter-node from bottom of plant and last inter-node (top of plant), sucrose concentration in juice was low and hence the brix percentage was minimum. But in 10 to 25 th inter-node, it was very high as sucrose accumulation was highest in these portion of the plant. Top portion of the plant with high magnitude of

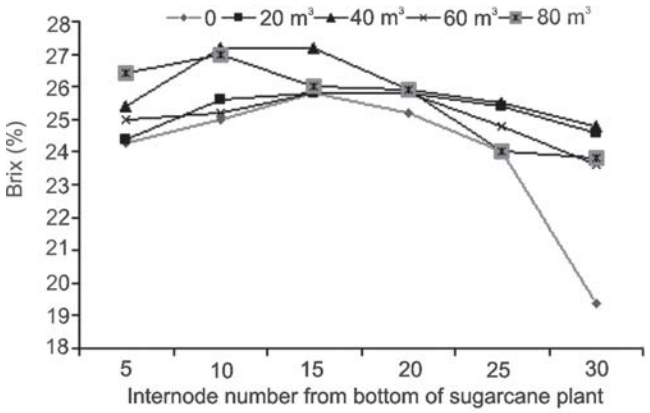


Fig 2 Brix value in between internode at harvest

photosynthate translocation from top to bottom resulted into less sucrose content as compared to the middle portion of the plant. Similarly, continuous absorption of water from soil through root also resulted into low sucrose content at the bottom internodes of the plant. When soil moisture by gravimetric content was estimated just before harvest of the crop, it was 7.54, 9.20, 8.89, 8.78% and 8.69% in fresh water, 20, 40, 60 and 80 m^3/ha distillery effluent treated plot, respectively. The corresponding value with respect to moisture content in three leaf from the top of plant was 62. 9, 63.4, 62.8, 62.4 and 61.9%; in seven leaf it was 59.4, 61.7, 60.9, 60.9 and 60.5%. This indicates that more amount of water in top portion of leaf had less sucrose concentration than below portion of the plant. Sarah and Thomas (2008) in

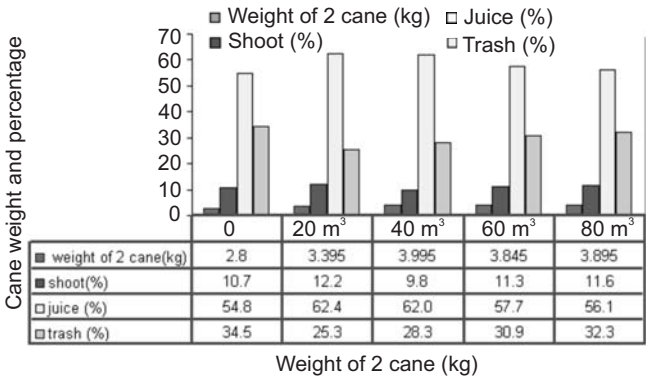
USA screened different sugarcane germplasm (from Louisiana and Hawai) for its growth and sucrose content under different soil water environment and found that total sugar concentration and sucrose: total sugar ratio in the inter node were negatively correlated with water content, soluble acid invertase and neutral invertase activity. The present trend of sucrose concentration in different internodes corroborate with above findings.

Further, to assess the magnitude of relationship between brix value and number of inter-node the second degree polynomial was done by considering number of inter-node as input variable (X value) and observed brix as output variable (Y value). The co-efficient derived in the following equations reveals that minimum R^2 value in 40 m^2/ha distillery effluent represent more uniformity in concentration of sucrose content in whole plant as compared to remaining treatments. More uniformity in sucrose content in different inter-nodes contributed to more sugar yield.

Control	$Y = -0.6161x^2 + 3.5096x + 21.01$	$R^2 = 0.9456$
20 m^3/ha	$Y=-0.2214x^2 + 1.5614x + 23.16$	$R^2 = 0.9680$
40 m^3/ha	$Y=-0.2518x^2 + 1.4939x + 24.59$	$R^2 = 0.7346$
60 m^3/ha	$Y=-0.2393x^2 + 1.4407x + 23.62$	$R^2 = 0.9351$
80 m^3/ha	$Y=-0.1357x^2 + 0.3186x + 26.46$	$R^2 = 0.8904$

Application of distillery effluents improved crop growth and sugarcane yield as compared to fresh water alone, however the distribution of juice, trash and fresh shoot of plant significantly differentiated under distillery effluents. Out of total plant weight, the amount of juice in cane ranged from 58.7 to 65% and trash ranged from 28.9 to 30.2% and shoot ranged from 9.8 to 12.2%. With respect to effect of different levels of distillery effluents, increasing quantity of distillery effluents decreased amount of juice in the sugarcane and increased amount of trash and shoot. Application of highest amount of distillery (80 m^3/ha) had 58.2% juice and 32. 3% trash but the fresh water treatment had 67.3% juice and 23.5% trash. Remaining treatment had 57.7 to 62.4% juice and 21.6 to 28.3% trash (Fig 3).

Total crop ET during planting to harvest of sugarcane was 1513.9 mm, however total rainfall received during the corresponding period was 1042.4 mm. During hot months



	0	20 m^3	40 m^3	60 m^3	80 m^3
weight of 2 cane(kg)	2.8	3.395	3.995	3.845	3.895
shoot(%)	10.7	12.2	9.8	11.3	11.6
juice (%)	54.8	62.4	62.0	57.7	56.1
trash (%)	34.5	25.3	28.3	30.9	32.3

Fig 3 Weight of two canes and its distribution in juice, trash, shoot at harvest

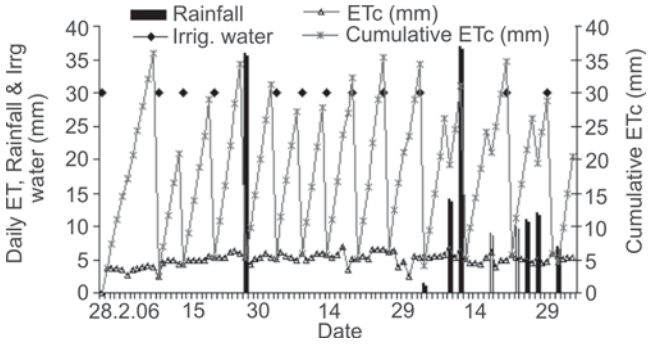


Fig 4 Irrigation requirement of sugarcane

period (February to May), the crop ET was 529.5 mm but rainfall amount was only 101.4 mm This huge amount of deficit crop demand was fulfilled by frequent irrigations as depicted in Fig 4. During this hot month period, relative humidity was low, temperature was very high (max. temperature 35.4 to 38.2°c and min. temperature 15.9 to 25.8°c). Such high atmospheric demand generally damages crop growth if sufficient amount and frequent irrigation is not followed. During rainy season (June to September) crop ET demand was lower (592.3 mm) than rainfall received (832 mm) and hence no irrigation was provided to this crop. But in October to January the crop ET was 392.05 mm and rainfall was only 34 mm and hence three irrigations one each in October, November and December 2006 was provided to the crop. So during the complete crop growth period about 15 irrigations were applied. In practice, irrigation is supplied at 60 to 75 mm cumulative pan evaporation value based on the soil properties but in this experiment very frequent irrigation through pipe was provided to keep the rooting zone moist as heavy load of chemical ingredients could have been damaged the crop if frequent irrigation schedule was not followed.

Orissa has 46 lakh ha area in upland and medium land where rice crop is being grown in large scale. The rice productivity in these lands is very low. If sugarcane is cultivated in such type of land topography and use distillery effluents of sugar industries @ 40 m^3/ha, then good amount of returns could be obtained. In other crops also the distillery effluents can be used but further study is required to assess quantum of severity on crop performance.

SUMMARY

Field experiment was conducted in experimental farm of Sakti Sugar Industries, Dhenkanal, Orissa to study the effect of different levels of distillery effluent application on the crop growth, yield and soil health. The results revealed that application of distillery effluents from sugar factory affected sugarcane yield, crop growth and quality of cane juice when it was applied beyond 40 m^3/ha in sugarcane crop. In light textured upland soils, application of 40 m^3/ha distillery effluents was found to be most economical level for sugarcane

production. The brix, polarity, commercial cane sugar was very high at this rate. Crop performance, like tillers, plant height, number of functional leaves were also affected badly beyond 40 m^3/ha application dose. Soil health was also improved with application of 40 m^3 distillery effluents, the magnitude being 28% nitrogen, 27% potassium, 58% calcium, 597% magnesium, 87% iron over the control treatment. Beyond above dose of distillery effluents, due to presence of other toxic ions the growth of the plant and crop yield was deteriorated at significant level.

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