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Improved *In situ* decomposition technique in sugarcane land use system for sustainable sugarcane productivity and soil health

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Abstract
A field experiment was conducted at Central Sugarcane Research Station, Padegaon in preseasonal sugarcane (2015) with its three successive ratoons (2017-20) in split plot design with three replications with an object to assess the effect of recycling of sugarcane crop residues and it's industrial wastes on yield, quality and nutrient uptake of sugarcane, study the soil properties as influenced by decomposition of sugarcane crop residues and it's industrial wastes, to assess the changes in soil organic carbon as influenced by various treatments of *in situ* decomposition of sugarcane crop residues and industrial wastes and to assess the possibility of saving of chemical fertilizers. The experimental results recorded and mentioned during preseasonal sugarcane and its three ratoons. It consists of main plot treatment as sugarcane crop residues and industrial wastes management with sub plot treatment comprising fertilizer levels. *In situ* recycling of sugarcane crop residues + press mud compost + post biomethanated spent wash + bagasse ash recorded significantly higher cane yield, CCS yield, average cane weight and number of millable canes per hectare also improved physicochemical properties of soil. However, effect of fertilizer levels results showed that the fertilizer level receiving 100% recommended dose of fertilizers recorded significantly higher cane yield, CCS yield, average cane weight and number of millable canes and it was at par with 75% recommended dose of fertilizers in respect to cane yield, CCS yield, average cane weight and number of millable canes and at par with 50% recommended dose of fertilizer in respect to average cane weight. While in terms of soil chemical parameters showed significant results for organic carbon, available nitrogen, available phosphorus and available potassium as compared to soil initial status. The significantly higher total uptake of nitrogen, phosphorus and potassium were noticed in sugarcane at harvest. The higher gross and net return were observed in the *In situ* recycling of sugarcane crop residues + press mud compost + Post biomethanated spent wash + bagasse ash (Rs. 3,14,879 and Rs. 2,31,749) with higher benefit cost ratio (2.83). The 100% recommended dose of fertilizer recorded significantly higher gross and net return (Rs. 3,18,617and Rs. 2,29,718) while higher benefit cost ratio (2.57) was recorded in both 100 and 50% recommended dose of fertilizer. Thus, result shows that decomposition of sugarcane crop residue and industrial wastes along with 100% or 75% recommended dose of fertilizers found to be better for enhance farmers income as well as improves soil health.

Keywords: *In situ* trash management, sugarcane industrial waste, recycling of sugarcane crop residue, pressmud compost, post biomethanated spent wash, bagasse ash

Introduction
Sugarcane industry is facing many challenges. Currently, it is sandwiched between increasing cost of production and decreasing yields. Sugarcane crop requires large quantity of nutrients as it remains in the field for longer period. Due to indiscriminate use of water and fertilizers, continuous growing of sugarcane after sugarcane, the fertility and productivity of soil is depleting. Under this situation, it is essential to use of available organic wastes for improving soil health and yield. Presently there is no any other *In situ* decomposition technique in sugarcane land use system with use industrial waste. Generally, cane trash contains 68% organic matter, 0.42% N, 0.15% P, 0.57% K, 0.48% Ca and 0.12% Mg, besides 25.7, 2045, 236.4 and 16.8 ppm Zn, Fe, Mn and Ca, respectively (Srivastava *et al.* 1992). At Coimbatore, soil temperature was reduced by 2.1 °C under trash cover, creating more favorable environment for crop growth (Sundara 1998) [5]. Now days the Central Pollution Control Board, New Delhi has banned the soil application of spent wash by imposing gazette, however only utilization of spent wash in the composting process is possible. There is no any concrete recommendation for management of sugarcane crop residue and industrial waste after harvest of sugarcane ratoon. Therefore, present study was, conducted to develop *in situ* decomposition technique for recycling of available sugarcane crop residues and industrial wastes for

improving sugarcane productivity and soil health.

Materials and Methods

A field experiment was conducted at CSRS, Padegaon in preseasonal sugarcane (2015) with its three successive ratoons (2017-20) in split plot design with three replications. In this experiment Sannhemp green manure-sugarcane-ratoon sequence was undertaken. The two eye bud sugarcane setts of variety CoM 0265 with row spacing 120 x 15 cm with recommended dose of fertilizer 340:170:170 (plant) and 250:115:115 (ratoon) N, P_2O_5 and K_2O kg ha^{-1}. The seven treatments imposed included in main plot as sugarcane crop residue and industrial wastes management as T_1- Burning of sugarcane trash (Farmers practice–I), T_2- Removal of sugarcane trash (Farmers practice-II), T_3- *In situ* decomposition of sugarcane crop residues, T_4- T_3 + post biomethanated spent wash, T_5- T_3 + pressmud compost, T_6- T_3 + pressmud compost + post biomethanated spent wash and T_7- T_3 + pressmud compost + post biomethanated spent wash+ bagasse ash. While sub plot treatments comprises four level of recommended dose of fertilizer (RDF) viz., F_0-control, F_1-50% RDF, F_2-75% RDF and F_3- 100% RDF. The quantity of sugarcane crop residues viz. sugarcane trash and industrial wastes viz., pressmud compost, post biomethanated spent wash and bagasse ash generated from harvested sugarcane ratoon field is utilized for conduct of experiment. The main plot treatments are imposed after harvest of previous sugarcane ratoon crop. After three months *in situ* decomposition of sugarcane crop residues the sub plot treatments are superimposed without disturbing the original layout. For decomposition of 1 tonne sugarcane crop residues added 8 kg urea + 10 kg SSP + 1 kg decomposing culture. Application of decomposing culture which consists of *Trichoderma hergiunum, Trichoderma viride, Penecillium digitatum, Chetomium* spp. having viable cell count 10^{-7} used. The initial soil status was pH 7.55, E.C.0.36 dS m^{-1}, O.C. 0.63%, B.D. 1.39 Mgm^{-3}, Porosity 47.60% and MWHC 57.35%, available N 178.24 kg ha^{-1}, available P 27.00 kg ha^{-1} and available K 302.00kg ha^{-1}. Statistical analysis of the sugarcane data was worked out as per the method described by Panse and Sukhatme (1967) [3].

Quantity of applied sugarcane crop residues and industrial wastes per hectare

Sr. No.	Particular		Quantity (ha^{-1})
1	Sugarcane crop residue	Sugarcane trash	12 tonne
2	Sugarcane industrial waste	Pressmud compost	2.26 tonne
3		Post biomethanated spent wash (PBSW)	13,560 liter
4		Bagasse ash	339 kg

Results and Discussion

1. Yield Parameters

The pooled data of yield parameters of sugarcane crop residues and industrial wastes management are presented in Table 1. It showed that the treatment T_7 receiving *In situ* decomposition of sugarcane crop residues + pressmud compost + post biomethanated spent wash+ bagasse ash recorded significantly higher cane yield (124.73 t ha^{-1}) and CCS yield (16.43 t ha^{-1}) than rest of treatments however, it was at par with T_6, T_5 and T_4. Effect of fertilizer levels results showed that use of 100% recommended dose of fertilizers recorded significantly higher cane and CCS yield (110.04 t ha^{-1} and 16.26 t ha^{-1}). However, it was at par with 75% recommended dose of fertilizers. These findings are in conformity with results of Tayade (2016) [6].

2. Yield contributing and quality parameters

The pooled data of yield contributing and quality parameters of sugarcane crop residues and industrial wastes management are presented in Table 2. It showed that the treatment T_7 receiving *In situ* decomposition of sugarcane crop residues + press mud compost + post biomethanated spent wash+ bagasse ash recorded significantly higher average cane weight (1.67 kg) and number of millable cane (69.88 '000' ha^{-1}) than rest of treatments however, it was at par with T_6, T_5 and T_4. Effect of fertilizer levels results showed that use of 100% recommended dose of fertilizers recorded significantly higher average cane weight (1.69 kg) and number of millable cane (69.41 '000' ha^{-1})). However, it was at par with 75% recommended dose of fertilizers in respect to cane yield, CCS yield, average cane weight and number of millable canes and at par with 50% recommended dose of fertilizer in respect to average cane weight. These findings are in conformity with results of Tayade (2016) [6]. While CCS per cent was statistically non-significant. While quality parameters like brix, sucrose, CCS and purity per cent were statistically non-significant.

3. Soil residual properties and nutrient uptake

The pooled data of nutrient uptake by sugarcane and soil residual physical and chemical parameters at harvest are presented in Table 3.

3.1 Soil physical properties

The effect of sugarcane crop residues and industrial wastes management on physical properties of soil revealed that the lowest bulk density, higher porosity and maximum water holding capacity (1.27 mg m^3, 51.46% and 62.70%) were observed in the treatment T_7 receiving *In situ* decomposition of sugarcane crop residues + pressmud compost + post biomethanated spent wash + bagasse ash. However, porosity and water holding capacity were at par with treatment T_6. *In situ* sugarcane crop residues and industrial wastes decomposition significantly improved larger macro-aggregates as compared to burning of crop residues. These results were resembled with the findings of Manna *et al.* (2007a and b). The significantly higher porosity and water holding capacity (60.34% and 49.76%) were recorded in 100% recommended dose of fertilizer however, it was at par with 75 and 50% recommended dose of fertilizer in respect of porosity percentage and at par with 75% recommended dose of fertilizer in respect of Maximum Water Holding Capacity. While effect of fertility levels on bulk density was found non-significant.

3.2 Soil chemical properties

Effect of sugarcane crop residues and industrial wastes management observed that soil organic carbon content was reduced in the inorganic treatments T_1 and T_2 and it was increased in all *In situ* decomposition of sugarcane crop residues and industrial waste treatments over its initial values. The treatment T_7 receiving *In situ* decomposition of sugarcane crop residues + pressmud compost + post biomethanated spent wash+ bagasse ash recorded significantly higher organic carbon (0.71%) and it was at par with treatment T_6, T_5 and T_4.

The lowest organic carbon was recorded in the treatment T_1 receiving Burning of sugarcane trash (0.60%). While non-significant effect of organic carbon was noticed in 100% RDF. Significantly the highest soil EC was noticed in treatment T_7 (0.44 dSm^{-1}) however, it was found at par with treatment T_4 and T_6 and the pH was found to be non-significant.

The values of available N, P and K were higher in treatment T_7 receiving *In situ* decomposition of sugarcane crop residues + pressmud compost + PBSW+ bagasse ash (260.15, 47.00 and 396.75 kg ha^{-1}, respectively) and it was at par with treatment T_6 in respect of available P. The application of 100% recommended dose of fertilizer observed significantly higher available N, P and K (248.92, 42.16 and 331. 92 kg ha^{-1}, respectively) and it was at par with 75% RDF in respect of available P. These findings are in conformity with results of Phalke *et al.* (2017) [7] and Tayade *et al.* (2016) [6].

3.3 Total nutrient uptake

The pooled data of total nutrient uptake of sugarcane crop residues and industrial wastes management showed that the treatment T_7 receiving *In situ* decomposition of sugarcane crop residues + press mud compost + post biomethanated spent wash+ bagasse ash recorded significantly higher total N, P and K uptake (236.68, 42.61 and 281.94 kg ha^{-1}, respectively) than rest of treatments however, it was at par with T_6 in respect of total N and P uptake. Effect of fertilizer levels results showed that use of 100% recommended dose of fertilizers recorded significantly higher total N, P and K uptake (242.08, 42.27 and 282.09 kg ha^{-1}, respectively). However, it was at par with 75% recommended dose of fertilizers in respect of total N and P uptake. These findings are in conformity with results of Tayade *et al.* (2016) [6].

4. Economics

The pooled data on economics of different treatments are presented in table 2. It indicates that higher gross and net return were observed in the treatment T_7 receiving *In situ* recycling of sugarcane crop residues + press mud compost + PBSW + bagasse ash (Rs.3,14,879 and Rs.2,31,749). The higher benefit cost ratio was recorded in the treatment T_7 (2.83). While higher benefit cost ratio (2.57) was recorded in both 100 and 75% recommended dose of fertilizer.

Table 1: Effect of sugarcane crop residues and industrial wastes along with different fertilizers levels on sugarcane yield (Pooled)

Treatments	Cane Yield (t ha^{-1})					CCS Yield (t ha^{-1})				
	Plant Cane	**Ratoon I**	**Ratoon II**	**Ratoon III**	**Pooled**	**Plant Cane**	**Ratoon I**	**Ratoon II**	**Ratoon III**	**Pooled**
A. Main plot treatments (Sugarcane Crop Residues and Industrial Wastes)										
T_1: Burning of sugarcane trash (Farmers practice –I)	131.43	106.52	82.93	45.85	91.95	15.62	12.32	9.79	5.61	11.11
T_2: Removal of sugarcane trash (Farmers practice –II)	146.40	109.16	86.65	51.40	98.67	17.70	13.07	10.35	6.32	12.13
T_3: *In situ* decomposition of sugarcane crop residues	161.01	120.81	98.75	65.48	111.78	19.74	15.56	11.85	7.75	13.99
T_4: T_3 + Post biomethanated spent wash	164.67	122.32	101.25	69.44	114.69	20.40	15.83	12.30	8.35	14.49
T_5: T_3 + Pressmud compost	166.35	123.92	103.10	71.02	116.37	20.99	16.06	12.55	9.00	14.92
T_6: T_3 + Pressmud compost + Post biomethanated spent wash	171.60	127.73	108.89	77.19	121.62	21.55	16.59	13.46	9.48	15.54
T_7: T_3 + Pressmud compost + Post biomethanated spent wash + Bagasse ash	174.71	129.82	111.37	81.94	124.73	22.70	17.01	14.30	10.64	16.43
SE$\pm$	3.19	3.09	3.92	3.48	3.77	0.78	0.47	0.83	0.93	1.01
CD at 5%	10.84	9.52	11.98	12.87	11.73	2.37	1.46	2.39	2.63	2.18
B. Sub plot treatments (RDF Level)										
F_0: Without fertilizers	131.84	99.14	79.87	45.52	75.65	15.95	12.24	9.62	5.31	11.23
F_1: 50% recommended dose of fertilizers	156.73	115.07	93.54	60.59	90.54	19.45	14.23	11.37	7.55	13.60
F_2: 75% recommended dose of fertilizers	171.15	126.97	108.81	76.68	104.96	21.15	15.76	13.25	9.39	15.34
F_3: 100% recommended dose of fertilizers	176.23	132.55	113.72	81.42	110.04	22.25	16.49	14.03	10.46	16.26
SE$\pm$	2.07	2.28	2.63	4.78	3.50	0.39	0.33	0.38	0.66	0.73
CD at 5%	5.72	6.51	7.57	13.64	9.51	1.13	0.94	1.11	1.88	1.58
C. Interactions										
SE$\pm$	6.34	6.04	4.18	4.64	5.22	0.69	0.87	0.72	0.97	0.89
CD at 5%	17.78	17.24	12.03	13.40	14.49	2.00	2.48	2.01	2.79	2.45
General Mean	158.99	118.43	98.99	66.05	95.30	19.70	14.68	12.07	8.18	14.09

CCS	:	Commercial Cane Sugar

Table 2: Effect of sugarcane crop residues and industrial wastes along with different fertilizers levels on yield contributing, quality parameters and economics of different treatments at harvest (Pooled)

Treatments	ACW (kg)	NMC ('000' ha^{-1})	Brix (0^0)	Sucrose (%)	CCS (%)	Purity (%)	GMR ($Rs.ha^{-1}$)	Cost of culti. ($Rs.ha^{-1}$)	NMR ($Rs.ha^{-1}$)	B : C Ratio
A. Sugarcane crop residue and industrial wastes										
T_1: Burning of sugarcane trash (Farmers practice –I)	1.48	54.25	18.62	17.00	11.89	91.53	231038	75514	155524	2.04
T_2: Removal of sugarcane trash (Farmers practice –II)	1.53	58.49	19.18	17.35	12.09	91.22	248138	75514	172624	2.25
T_3: *In situ* decomposition of sugarcane crop residues	1.57	63.80	19.19	17.30	12.26	91.26	281642	81379	200262	2.49
T_4: T_3 + Post biomethanated spent wash	1.59	64.53	19.37	17.75	12.39	91.86	289125	81429	207695	2.58
T_5: T_3 + Pressmud compost	1.62	66.48	19.05	17.64	12.62	91.76	293392	82915	210476	2.57
T_6: T_3 + Pressmud compost + Post biomethanated spent wash	1.65	68.60	19.18	17.37	12.56	91.66	306847	82965	223881	2.73
T_7: T_3 + Pressmud compost + Post biomethanated spent wash + Bagasse ash	1.67	69.88	19.38	18.31	12.99	92.69	314879	83130	231749	2.83
SE$\pm$	0.03	2.03	0.32	0.43	0.35	0.39	--	--	--	--
CD at 5%	0.09	6.02	NS	NS	NS	NS	--	--	--	--
B. RDF Level										
F_0: Without fertilizers	1.55	55.63	19.00	17.19	12.12	91.65	223893	75514	148379	1.93
F_1: 50% recommended dose of fertilizers	1.62	62.41	19.17	17.56	12.43	91.53	268139	82236	185903	2.23
F_2: 75% recommended dose of fertilizers	1.67	66.36	19.12	17.59	12.38	91.89	307066	85543	221522	2.57
F_3: 100% recommended dose of fertilizers	1.69	69.41	19.24	17.65	12.64	91.78	318617	88900	229718	2.57
SE$\pm$	0.04	1.83	0.16	0.19	0.38	0.43	--	--	--	--
CD at 5%	0.12	4.60	NS	NS	NS	NS	--	--	--	--
C. Interactions										
SE$\pm$	0.12	6.14	0.29	0.33	0.39	0.30				
CD at 5%	NS	NS	NS	NS	NS	NS				
General Mean	1.64	63.45	19.13	17.50	12.39	91.71				

ACW	:	Average Cane Weight	NMC	:	Number of Millable Cane	GMR	:	Gross Monetary Return
B:C	:	Benefit Cost Ratio	CCS	:	Commercial Cane Sugar	NMR	:	Net Monetary Return

Table 3: Effect of sugarcane crop residues and industrial wastes along with different fertilizers levels on residual soil properties and total nutrient uptake at harvest (Pooled)

Treatments	BD (Mg m^{-3})	Porosity (%)	MWHC (%)	pH (1:2.5)	EC (dS m^{-1})	OC (%)	Available nutrient (kg ha^{-1})			Total nutrient uptake(kg ha^{-1})		
							N	P	K	N	P	K
A. Sugarcane crop residue and industrial wastes												
T_1: Burning of sugarcane trash (Farmers practice –I)	1.41	46.60	57.03	7.56	0.39	0.60	160.83	19.60	214.05	181.86	21.94	187.66
T_2: Removal of sugarcane trash (Farmers practice –II)	1.40	46.79	57.64	7.56	0.40	0.61	165.92	21.39	215.81	191.04	26.44	195.76
T_3: *In situ* decomposition of sugarcane crop residues	1.33	49.27	59.05	7.51	0.38	0.66	198.80	30.47	292.44	214.52	35.43	235.46
T_4: T_3 + Post biomethanated spent wash	1.32	49.55	58.98	7.50	0.44	0.69	229.21	34.53	351.64	218.71	37.21	256.60
T_5: T_3 + Pressmud compost	1.30	50.12	60.23	7.50	0.40	0.70	232.86	36.54	337.51	222.58	38.61	261.16
T_6: T_3 + Pressmud compost + Post biomethanated spent wash	1.29	50.70	61.91	7.49	0.44	0.70	246.81	44.35	374.52	232.49	40.95	274.66
T_7: T_3 + Pressmud compost + Post biomethanated spent wash + Bagasse ash	1.27	51.46	62.70	7.49	0.45	0.71	260.15	47.00	396.75	236.68	42.61	281.94
SE$\pm$	0.003	0.28	0.39	0.03	0.003	0.01	3.28	1.53	1.89	3.25	0.91	1.39
CD at 5%	0.01	0.87	0.92	NS	0.01	0.03	9.53	4.37	6.17	10.43	3.01	3.99
B. RDF Level												
F_0: Control	1.37	47.95	59.22	7.50	0.40	0.66	171.20	20.70	286.85	168.70	23.71	186.55
F_1: 50% RDF	1.32	49.48	59.37	7.50	0.40	0.67	206.45	32.38	310.36	209.61	32.93	226.05
F_2: 75% RDF	1.31	49.57	59.65	7.51	0.41	0.67	227.46	37.58	318.12	235.55	39.96	272.87
F_3: 100% RDF	1.31	49.76	60.34	7.52	0.41	0.68	248.92	42.16	331.92	242.08	42.27	282.09
SE$\pm$	0.02	0.23	0.27	0.02	0.02	0.01	3.14	1.43	1.29	3.53	0.91	1.87
CD at 5%	NS	0.59	0.81	NS	NS	0.02	9.17	5.14	3.89	10.92	2.88	6.02
C. Interactions												
SE$\pm$	0.05	2.19	2.11	0.05	0.04	0.02	6.25	3.27	5.43	7.82	3.54	7.99
CD at 5%	NS	NS	NS	NS	NS	0.05	NS	NS	NS	NS	NS	NS
General Mean	1.33	49.19	59.65	7.52	0.40	0.67	213.31	37.58	311.81	213.99	37.81	241.89

BD	:	Bulk Density	MWHC	:	Maximum Water Holding Capacity	EC	:	Electrical Conductivity	OC	:	Organic Carbon

Conclusion

Application of press mud compost @ 2.26 t ha^{-1} + 13560 L ha^{-1} of post biomethanated spent wash + 339 kg bagasse ash with 100 and 75% recommended dose of fertilizers to plant cane and its ratoon was found beneficial for increasing sugarcane yield and improving soil health.

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