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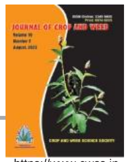

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Sugarcane seed crop nutrient dynamics with biofertilisers, trash mulching and chemical fertilizers

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ABSTRACT

A field study was conducted on seed cane crop at RARS, Anakapalle during 2019-20 and 2020-21, to investigate sugarcane seed crop nutrient dynamics with biofertilisers, trash mulching, and chemical fertilizers. It was designed in a split-plot design having three replications including three primary treatments: a control, biofertilizer combination and trash mulch, and applying N and K at different rates and times to the treatments in the sub plot. The paradigm showed that N, P and K uptake by seed cane and availability in soil after harvest were higher with integration of biofertilisers or trash mulch coupled with 125% soil test-based nitrogen and potassium (STBNK) applied at planting, 30, 60, 90 and 120 days after planting plus additional 25% RDK one month prior to harvest was comparable to 100% STBNK applied at planting, 30, 60, 90 and 120 days after planting plus 25% RDK one month prior to harvesting.

Keywords: Bio-decomposer, nutrient availability, nutrient uptake, seed cane and trash mulch

Sugarcane, among the most important and profitable crops in sub-tropical India, is rapidly losing its luster due to rising production costs and stagnant productivity (Singh and Srivastava, 2011). The higher N uptake of 162.4 kg ha^{-1} was observed with 100 % NPK + 20 t ha^{-1} BGS might be due to higher N availability. (Umesh *et al*., 2013). In plant as well as ratoon crop, three bud setts significantly increased N uptake, N use efficiency (167.2 and 147.9 kg cane/kg N applied) and apparent N recovery (59.1 and 49.7%), respectively (Kumar and Kumar, 2020).

In soil, typically contains less than 1.5%, but healthy crop production requires 2.5 to 3.0% organic matter (Bhander *et al*., 1998). 140 kg N, 34 kg P, and 332 kg K may be removed from the soil by a crop of 100 t cane yield (Dang *et al*., 1995). In addition, significant amounts of nutrients are lost due to leaching, denitrification, volatilization, etc. It's crucial to add organic manures and inorganic fertilisers at the right time and in the right mix in order to replenish these nutrients (Banerjee *et al*., 2018). In addition to sustaining soil and crop productivity, combined application of organic manures and inorganic fertilisers also preserves soil health and prevents the establishment of numerous nutrient deficits in the soil system (Umesh *et al*., 2013). Viridha and Patel (2010) reported the possibility of saving 25% N when organics were applied along with biofertilisers (*Azotobacter* + phosphate solubilizing bacteria).The use of bio-decomposer culture looks to be a promising solution for overcoming this gap, as it speeds up the decomposition process and adds organic matter to the soil while also providing immediate advantages. With this in mind, the objective of the study was to evaluate how the combined use of biofertilisers, trash mulching, and chemical fertilizers affected the nutrient dynamics of seed cane crop.

MATERIALS AND METHODS

The experiment was carried out at RARS, Anakapalle, Andhra Pradesh during 2019-20 and 2020-21. Soil samples from 0-30 cm depth were collected at random from the experimental site before layout of the experiment. Standard techniques were used to examine the physical and physico-chemical characteristics of a composite soil sample (Table 1). The experimental soil was sandy clay in texture neutral in reaction and medium in organic carbon. The study conducted with split-plot design having three treatments as main plots *i.e.*, M_1-control, M_2-biofertilisers and M_3 -trash mulch + decomposers A and B and six treatments as sub plots (different time and levels of fertilizer application) with three replications. The biofertilisers were mixed in 100

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kg FYM and kept for overnight and then applied in the field three days after planting of the crop as per the treatments (M_2) and trash mulching @ 3 t ha^{-1} was done on third day of planting and bio-decomposer mixed dung slurry was sprinkled on mulch for main plot M_3. The inorganic fertilizers *viz*., N, P and K were applied as per the soil test basis are presented in Table 1 (nitrogen was low in status for that additional 30% of recommended dose was applied, phosphorus status was high for that 30% of recommended dose was lowered and potassium status was medium for that normal recommended dose was applied). The recommended dose of NPK for seed cane is 112-100-120 kg ha^{-1}. Neem-coated urea, SSP, and MOP were used to apply nitrogen, phosphorus, and potassium, respectively. When necessary, irrigations were given. At 120 days old, the crop was manually earthed up. The "trash twist" method of trash twist p roping was used at the age of five months. Whole cane plant samples were collected at 60, 120, 180 DAP and at harvest, cut into pieces and fresh weight was taken then oven dried, powdered, dry weight was determined and analysed for nutrient contents of N, P and K using standard methods (Bremner, 1965; Koeing and Johnson, 1942 and Jackson, 1973, respectively). Nutrient uptake was calculated by multiplying the nutrient content with respective drymatter and expressed in kg ha^{-1}.

The split plot design's standard analysis of variance approach was used to analyse the data by Rangaswamy (2013).

RESULTS AND DISCUSSION

Plant nutrient uptake

Nitrogen uptake (kg ha^{-1})

At all growth stages, with the exception of 60 Days After Planting DAP, organic sources had a substantial impact on nutrient uptake over the course of the study's years and in the combined data. At 120 DAP, M_2 had appreciably increased the nitrogen uptake and was on par with M_3 (Table 2).

At 60 DAP, higher nitrogen uptake by seed crop was registered with T_5 treatment. However, it was statistically on par with T_6, T_3 during 2019-20 and in pooled data and with S_6, S_3 and S_4 during 2020-21 whereas S_5 exhibited superiority over S_2 and S_1 during 2020-21 and in addition to S_2 and S_1, S_4 also found inferior during first year and in pooled data.

At 180 DAP, S_5 exhibited significantly higher nitrogen uptake when compared to other treatments however, it was comparable with S_6 and S_3 treatments. The next best treatment was S_4 but inferior to S_5, S_6 and S_3 while it was superior to S_2 and S_1 during 2020-21. While in 2019-20 and in pooled data also, obviously S_5 treatment found to increase nitrogen uptake significantly over the rest of the treatments except with S_6. However, S_3 treatment also recorded higher nitrogen uptake and found comparable with S_6. Lower nitrogen uptake was observed with S_2 and was significantly inferior to all the treatments.

Under S_1, S_2, S_3 and S_4 fertilizer levels, application of biofertilisers and trash mulching were comparable with each other and both showed superior nitrogen uptake over control except at S_4 during 2020-21, where M_3 was on par with M_1. At S_5 fertilizer dose, M_2 was found on par with M_3 whereas M_1 recorded the significantly lower uptake of nitrogen over M_2 during 2019-20 and in pooled data but in 2020-21, all the main plots were statistically on par among themselves. At S_6 fertilizer dose, all the main plot treatments were comparable during 2020-21. However, M_2 maintained parity with M_3 and found superior over M_1 during the first year and in pooled data (Table 2a).

Phosphorus uptake (kg ha^{-1})

Phosphorus uptake increased gradually with advancement of crop age. The appreciably increased phosphorus uptake at 120 DAP, 180 DAP and at harvest was associated with the application of biofertilizer mixture (M_2) and statistically on par with M_3 and both were found significantly superior over control which recorded lower phosphorus uptake (Table 3). Babu (2009) and Jyothi and Rao (2020) also reported similar trend in seed crop of sugarcane.

Table 1: Chemical properties of the experimental soil (Initial)

S. No.	Properties	2019-20	2020-21	Method of analysis
1.	Organic carbon (%)	0.54	0.59	Modified Walkley and Black Method (Walkley and Black, 1934)
2.	Available N (kg ha^{-1})	232.7	244.0	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available P_2O_5 (kg ha^{-1})	66.4	72.8	Olsen's method (Olsen *et al*., 1954)
4.	Available K_2O (kg ha^{-1})	272.8	276.0	Neutral normal ammonium acetate method (Muhr *et al*., 1963)

Table 2: Nitrogen uptake (kg ha^{-1}) at different growth stages of sugarcane seed crop as influenced by biological nutrient management during 2019-20, 2020-21 and pooled data

Treatments	2019-20				2020-21				Pooled data			
	60 DAP	120 DAP	180 DAP	At harvest	60 DAP	120 DAP	180 DAP	At harvest	60 DAP	120 DAP	180 DAP	At harvest
Organic sources												
M_1	25.4	68.8	129.3	139.6	18.3	53.6	116.0	126.2	21.8	61.2	122.6	132.9
M_2	28.0	85.0	176.4	183.2	19.8	65.3	152.9	157.2	23.9	75.2	164.7	170.2
M_3	28.0	83.2	166.9	180.7	19.3	64.4	146.7	152.0	23.6	73.8	156.8	166.4
SEm(±)	0.86	2.68	4.30	5.91	0.69	2.15	4.11	4.55	0.61	1.93	2.82	4.91
LSD(0.05)	NS	10.5	16.9	23.2	NS	8.5	16.1	17.8	NS	7.6	11.1	19.3
CV (%)	13.5	14.4	11.6	14.9	15.3	15.0	12.6	13.3	11.2	11.7	8.1	13.3
Time and dose of N & K application												
S_1	23.2	66.2	126.8	149.7	16.9	53.7	110.2	124.3	20.1	60.0	118.5	137.0
S_2	21.7	61.4	116.4	142.2	16.2	50.7	98.5	114.5	19.0	56.0	107.4	128.4
S_3	29.1	85.2	176.1	178.7	20.1	63.6	155.4	156.3	24.6	74.4	165.8	167.5
S_4	27.4	77.6	157.9	161.7	19.2	61.5	140.1	142.6	23.3	69.5	149.0	152.2
S_5	31.3	96.3	188.1	192.3	21.6	71.6	165.8	170.3	26.4	84.0	176.9	181.3
S_6	30.2	87.5	179.9	182.6	20.6	65.6	161.2	162.7	25.4	76.5	170.5	172.6
SEm(±)	1.16	3.75	3.34	7.09	0.86	2.72	4.26	6.40	0.85	2.59	3.23	5.41
LSD(0.05)	3.4	10.8	9.6	20.5	2.5	7.9	12.3	18.5	2.5	7.5	9.3	15.6
CV (%)	12.8	14.2	6.4	12.7	13.5	13.4	9.2	13.2	11.1	11.1	6.5	10.4
Interaction	NS	NS	S	NS	NS	NS	S	NS	NS	NS	S	NS

Note: M_1 - No Biofertilisers, M_2 - Biofertilizer mixture (*Azospirillum*, PSB, KRB each @ 1250 ml ha^{-1} & VAM @ 12.5 kg ha^{-1}, M_3 - Trash mulching with bio-decomposer (A & B), S_1 -75% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_2 - 75% STBNK at planting, 45, 90, 135 & 180 DAP, S_3 - 100% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_4 - 100% STBNK at planting, 45, 90, 135 & 180 DAP, S_5 - 125% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_6 - 125% STBNK at planting, 45, 90, 135 & 180 DAP.

Table 2a : Interaction between organic sources, time and dose of nitrogen and potassium application on nitrogen uptake (kg ha^{-1}) by sugarcane seed crop at 180 DAP as influenced by biological nutrient management during 2019-20, 2020-21 and pooled data

Time and dose of nitrogen and potassium application	Organic sources (2019-20)			Mean	Organic sources (2020-21)			Mean	Organic sources (Pooled data)			
	M_1	M_2	M_3		M_1	M_2	M_3		M_1	M_2	M_3	Mean
S_1	100.2	142.6	137.6	126.8	75.8	128.0	126.9	110.2	88.0	135.3	132.2	118.5
S_2	71.1	139.2	138.9	116.4	64.4	123.0	108.1	98.5	67.8	131.1	123.5	107.4
S_3	154.8	192.6	181.1	176.1	126.5	171.9	167.9	155.4	140.6	182.3	174.5	165.8
S_4	127.6	176.1	170.0	157.9	119.6	156.7	144.0	140.1	123.6	166.4	157.0	149.0
S_5	166.5	204.4	193.4	188.1	159.4	167.3	170.6	165.8	163.0	185.9	182.0	176.9
S_6	155.4	203.6	180.7	179.9	150.6	170.5	162.5	161.2	153.0	187.0	171.6	170.5
Mean	129.3	176.4	166.9		116.0	152.9	146.7		122.6	164.7	156.8	
	SEm(±)	**LSD (0.05)**	**CV (%)**		**SEm(±)**	**LSD (0.05)**	**CV (%)**		**SEm(±)**	**LSD (0.05)**	**CV (%)**	
Organic Sources (M)	4.30	16.9	11.6		4.11	16.1	12.6		2.82	11.1	8.1	
Time and dose of nitrogen & potassium application (S)	3.34	9.6	6.4		4.26	12.3	9.2		3.23	9.3	6.5	
Interaction												
M*S	5.78	16.7		7.39	21.3		5.60	16.2				
S*M	7.69	25.3		8.38	27.0		6.06	19.4				

Table 3: Phosphorus uptake (kg ha^{-1}) at different growth stages of sugarcane seed crop as influenced by biological nutrient management during 2019-20, 2020-21 and pooled data

Treatments	2019-20				2020-21				Pooled data			
	60 DAP	120 DAP	180 DAP	At harvest	60 DAP	120 DAP	180 DAP	At harvest	60 DAP	120 DAP	180 DAP	At harvest
Organic sources												
M_1	4.2	14.6	35.5	36.2	2.9	11.1	31.3	34.7	3.6	12.9	33.4	35.5
M_2	4.6	17.7	48.0	49.9	3.2	13.5	41.9	44.8	3.9	15.6	45.0	47.3
M_3	4.6	17.0	45.3	47.5	3.2	13.2	40.6	42.3	3.9	15.2	43.0	44.9
SEm(±)	0.16	0.59	1.24	1.22	0.11	0.42	1.23	0.63	0.12	0.40	1.25	0.90
LSD(0.05)	NS	2.3	4.9	4.8	NS	1.6	4.8	2.5	NS	1.6	4.9	3.5
CV (%)	14.9	15.2	12.3	11.6	15.4	14.1	13.7	6.6	13.2	11.6	13.1	9.0
Time and dose of N & K application												
S_1	3.8	13.6	37.0	38.8	2.8	11.2	30.5	32.7	3.3	12.4	33.8	35.8
S_2	3.7	12.4	34.6	36.9	2.8	10.7	28.1	30.9	3.2	11.6	31.4	33.9
S_3	4.7	17.9	47.5	49.1	3.3	13.0	42.0	44.5	4.0	15.5	44.8	46.8
S_4	4.5	16.0	40.9	41.6	3.1	12.4	39.1	42.5	3.8	14.2	40.0	42.1
S_5	5.1	19.8	49.8	51.2	3.4	14.6	45.2	47.3	4.3	17.2	47.5	49.2
S_6	5.0	18.9	47.7	49.4	3.3	13.6	42.8	45.6	4.2	16.3	45.2	47.5
SEm(±)	0.22	0.80	1.77	1.16	0.12	0.58	1.65	0.87	0.17	0.54	1.39	0.96
LSD(0.05)	0.6	2.3	5.1	3.3	0.3	1.7	4.8	2.5	0.5	1.6	4.0	2.8
CV (%)	14.5	14.6	12.3	7.8	11.2	13.8	13.0	6.4	13.0	11.2	10.3	6.7
Interaction	NS	NS	NS	S	NS	NS	NS	S	NS	NS	NS	S

Note: M_1 - No Biofertilisers, M_2 - Biofertilizer mixture (*Azospirillum*, PSB, KRB each @ 1250 ml ha^{-1} & VAM @ 12.5 kg ha^{-1}, M_3 - Trash mulching with bio-decomposer (A & B), S_1 -75% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_2 - 75% STBNK at planting, 45, 90, 135 & 180 DAP, S_3 - 100% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_4 - 100% STBNK at planting, 45, 90, 135 & 180 DAP, S_5 - 125% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_6 - 125% STBNK at planting, 45, 90, 135 & 180 DAP.

Table 3a :Interaction between organic sources, time and dose of nitrogen and potassium application on phosphorus uptake (kg ha^{-1}) by sugarcane seed crop at harvest as influenced by biological nutrient management during 2019-20, 2020-21 and pooled data

Time and dose of nitrogen and potassium application	Organic sources (2019-20)			Mean	Organic sources (2020-21)			Mean	Organic sources (Pooled data)			
	M_1	M_2	M_3		M_1	M_2	M_3		M_1	M_2	M_3	Mean
S_1	28.3	43.6	44.6	38.8	25.2	36.9	36.1	32.7	26.8	40.3	40.4	35.8
S_2	23.7	43.7	43.4	36.9	20.9	36.9	34.9	30.9	22.3	40.3	39.2	33.9
S_3	43.4	55.4	48.5	49.1	39.8	49.0	44.7	44.5	41.6	52.2	46.6	46.8
S_4	34.0	46.1	44.8	41.6	39.3	45.1	43.1	42.5	36.7	45.6	44.0	42.1
S_5	44.0	55.3	54.2	51.2	42.0	51.6	48.2	47.3	43.0	53.5	51.2	49.2
S_6	43.5	55.3	49.2	49.4	41.0	49.0	46.8	45.6	42.3	52.2	48.0	47.5
Mean	36.2	49.9	47.5		34.7	44.8	42.3		35.50	47.3	44.9	
	SEm(±)	**LSD (0.05)**	**CV (%)**		**SEm(±)**	**LSD (0.05)**	**CV (%)**		**SEm±**	**CD (p = 0.05)**	**CV (%)**	
Organic Sources (M)	1.22	4.8	11.6		0.63	2.5	6.6		0.90	3.5	9.0	
Time and dose of nitrogen & potassium application (S)	1.16	3.3	7.8		0.87	2.5	6.4		0.96	2.8	6.7	
Interaction												
M*S	2.00	5.8		1.51	4.4		1.66	4.8				
S*M	2.37	7.7		1.52	4.8		1.86	6.0				

Table 4: Potassium uptake (kg ha^{-1}) at different growth stages of sugarcane seed crop as influenced by biological nutrient management during 2019-20, 2020-21 and pooled data

Treatments	2019-20				2020-21				Pooled data			
	60 DAP	120 DAP	180 DAP	At harvest	60 DAP	120 DAP	180 DAP	At harvest	60 DAP	120 DAP	180 DAP	At harvest
Organic sources												
M_1	19.0	65.6	155.0	157.9	13.7	49.2	136.0	147.2	16.4	57.4	145.5	152.6
M_2	20.5	80.9	205.8	208.2	14.8	61.9	183.6	194.3	17.7	71.4	194.7	201.3
M_3	20.2	80.5	191.9	204.5	14.6	60.6	173.2	187.1	17.4	70.6	182.6	195.8
SEm(±)	0.68	2.65	6.05	6.53	0.42	1.88	6.11	4.96	0.50	2.02	5.98	4.68
LSD(0.05)	NS	10.4	23.7	25.7	NS	7.4	24.0	19.5	NS	7.9	23.5	18.4
CV (%)	14.6	14.9	13.9	14.6	12.4	13.9	15.8	11.9	12.4	12.9	14.6	10.8
Time and dose of N & K application												
S_1	17.5	63.9	158.5	164.6	12.8	51.7	132.1	149.0	15.2	57.9	145.3	156.8
S_2	16.8	60.7	143.6	158.3	12.5	48.7	116.5	141.5	14.7	54.7	130.1	149.9
S_3	21.0	80.8	198.6	206.4	15.2	58.9	186.8	190.8	18.1	69.9	192.7	198.6
S_4	20.0	74.0	184.3	189.0	14.4	55.7	162.4	176.7	17.2	64.9	173.4	182.9
S_5	22.4	89.5	215.7	216.0	15.9	67.1	198.7	202.6	19.2	78.3	207.2	209.3
S_6	21.8	84.9	204.6	206.9	15.5	61.4	189.2	196.7	18.7	73.2	196.9	201.8
SEm(±)	0.94	3.68	7.91	9.24	0.53	2.65	6.30	6.13	0.70	2.39	6.08	6.55
LSD(0.05)	2.7	10.6	22.9	26.7	1.5	7.7	18.2	17.7	2.0	6.9	17.6	18.9
CV (%)	14.2	14.6	12.9	14.6	11.1	13.9	11.5	10.4	12.2	10.8	10.5	10.7
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: M_1 - No Biofertilisers, M_2 - Biofertilizer mixture (*Azospirillum*, PSB, KRB each @ 1250 ml ha^{-1} & VAM @ 12.5 kg ha^{-1}, M_3 - Trash mulching with bio-decomposer (A & B), S_1 -75% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_2 - 75% STBNK at planting, 45, 90, 135 & 180 DAP, S_3 - 100% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_4 - 100% STBNK at planting, 45, 90, 135 & 180 DAP, S_5 - 125% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_6 - 125% STBNK at planting, 45, 90, 135 & 180 DAP.

Table 5: NPK availability (kg ha^{-1}) in soil after harvest of sugarcane seed crop as influenced by biological nutrient management during 2019-20, 2020-21 and pooled data

Treatments	2019-20			2020-21			Pooled data		
	N	P	K	N	P	K	N	P	K
Organic sources									
M_1	173.0	65.0	191.2	161.0	60.3	190.8	167.0	62.6	191.0
M_2	189.9	76.1	217.3	182.3	69.2	212.8	186.1	72.6	215.1
M_3	186.4	73.5	216.0	180.7	66.3	209.0	183.6	69.9	212.5
SEm(±)	3.19	2.14	4.79	4.31	1.44	4.47	3.37	1.66	3.87
LSD(0.05)	12.5	8.4	18.8	16.9	5.7	17.5	13.2	6.5	15.2
CV (%)	7.4	12.7	9.8	10.5	9.4	9.3	8.0	10.3	8.0
Time and dose of N & K application									
S_1	173.0	66.1	200.4	165.9	60.9	195.2	169.4	63.5	197.8
S_2	169.5	65.6	196.1	161.4	60.6	189.3	165.4	63.1	192.7
S_3	184.4	74.1	213.0	180.1	67.7	208.7	182.3	70.9	210.9
S_4	183.0	73.9	203.5	177.6	66.5	204.3	180.3	70.2	203.9
S_5	194.8	75.3	222.5	184.4	68.6	218.0	189.6	71.9	220.3
S_6	194.1	74.2	213.5	178.6	67.4	209.9	186.3	70.8	211.7
SEm(±)	6.57	2.67	6.17	5.29	2.03	6.28	5.72	1.88	5.40
LSD(0.05)	19.0	7.7	17.8	15.3	5.9	18.1	16.5	5.4	15.6
CV (%)	10.8	11.2	8.9	9.1	9.3	9.2	9.6	8.3	7.9
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: M_1 - No Biofertilisers, M_2 - Biofertilizer mixture (*Azospirillum*, PSB, KRB each @ 1250 ml ha^{-1} & VAM @ 12.5 kg ha^{-1}, M_3 - Trash mulching with bio-decomposer (A & B), S_1 -75% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_2 - 75% STBNK at planting, 45, 90, 135 & 180 DAP, S_3 - 100% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_4 - 100% STBNK at planting, 45, 90, 135 & 180 DAP, S_5 - 125% STBNK at planting, 30, 60, 90, 120 DAP + 25% recommended K one month before harvesting, S_6 - 125% STBNK at planting, 45, 90, 135 & 180 DAP.

At 60 DAP, S_5 registered higher phosphorus uptake and was comparable with S_6, S_3 and S_4. The phosphorus uptake in whole cane was higher in S_5 treatment, which was significantly superior to other treatments and statistically on par with S_6 and S_3 treatments. A Similar trend was noticed at 180 DAP during 2019-20, 2020-21 and in combined data as well. Higher phosphorus uptake was observed with S_5 treatment which was significant superior to all other treatments except with S_6 treatment in pooled data and with S_6 and S_3 treatments during 2020-21 and significantly superior to S_4, S_2 and S_1 treatments.

At harvest, increased phosphorus uptake was observed with S_5 treatment and was significantly superior to all the other treatments studied in this study whereas, S_5 maintained parity with S_6 and S_3 during 2019-20 and in pooled data and with S_6 only during 2020-21. Treatment S_2 recorded lower phosphorus uptake during both the study years and in combined data.

The interaction effect of main plots and sub plots had failed to hold significant influence on phosphorus uptake at all crop stages except at harvest. At all the main plot treatments, S_5 recorded higher phosphorus uptake than S_2 and S_1 treatments however maintained statistical parity with S_6 treatment. The application of lower fertilizer dose along with biofertilisers (M_2S_2 and M_2S_1) and trash mulch (M_3S_2 and M_3S_1) was found on par with that of application of 125% STBNK + additional 25% RDK (M_1S_5) during the first year of study and also in pooled data (Table 3a).

Potassium uptake (kg ha^{-1})

A perusal of the data in Table 4 revealed that variation in potassium uptake was significantly altered by different organic sources studied in the experiment at different stages and at harvest except at 60 DAP. Potassium uptake by whole cane plant was higher in biofertilizer applied treatment (M_2) and found on par with M_3 and both inturn superior to control at 120 DAP during both the study years and in combined data. The differences in potassium uptake of seed cane noticed at 180 DAP and at harvest were also followed the same pattern during both the study years of experimentation and in combined data.

The doses and time of nitrogen and potassium application had significant influence on K uptake at all the stages of crop growth. Among all the treatments, at 60 DAP, the higher potassium uptake was displayed with S_5. However treatments S_5, S_6, S_3 and S_4 were comparable. Lower potassium uptake was recorded with S_2 followed by S_1.

Higher potassium uptake was recorded with S_5 treatment and maintained parity with S_6 and S_3 during 2019-20 and with only S_6 during 2020-21 and in pooled data. The treatment S_3 was followed by S_4 and both was found statistically on par with each other. The least potassium uptake was observed in S_2 followed by S_1 treatment at 120 DAP and at harvest.

At 180 DAP, during the first year similar trend of treatment influence on potassium uptake was exhibited as that noticed at 120 DAP during first year of experimentation.

Availability of soil nutrients after harvest

Nitrogen availability (kg ha^{-1})

In the first year of experimentation, among main plot treatments, M_2 recorded higher nitrogen availability in soil, which was on par with trash mulching. The lower soil available nitrogen was recorded with control, which is significantly inferior to all other treatments. Identical trend was noticed during 2020-21 and in combined data. Shankaraiah (2007) and Lakshmi *et al*. (2019) also reported similar results (Table 5).

S_5 treatment exhibited significantly higher nitrogen availability over S_2 followed by S_1. However, S_5 treatment was on par with S_6, S_3 and S_4. Conspicuously, lower nitrogen availability was associated with S_2 followed by S_1. These results are in tune with the results of Shankaraiah (2007) and Kumar and Kumar (2020).

Phosphorus availability (kg ha^{-1})

Post-harvest phosphorus availability was higher with M_2 and comparable with M_3 with bio-decomposers and both displayed significant superiority over control (Table 5). Current results are in conformity with Bhalerao *et al*. (2006) and Lakshmi *et al*. (2019).

Irrespective of year of the study, soil available phosphorus after harvest markedly increased in S_5 which was however statistically on par with S_6, S_3 and S_4. The S_2 registered distinctly lower available phosphorus in soil and was closely followed by S_1. Our results depicted in the present study corroborates with earlier findings of Mathew and Varughese (2007) and Kumar (2012).

Potassium availability (kg ha^{-1})

Potassium availability in Table 5 showed identical trend as observed in available N and K. Among various organic sources, M_2 increased the availability of potassium however it was comparable with M_3 and both shows significant superiority over control during 2019-20. Similar results were observed during 2020-21 and in combined data too. The present findings are supported by Bhalerao *et al*. (2006) and Banerjee *et al*. (2018). More post harvest availability of soil K with organic sources of nutrients could be ascribed to improved soil physical conditions and enhances microbial activity besides supplying nutrients which inturn lead to increased nutrient availability in soil.

Increased available potassium was manifested with S_5. However, it maintained parity with S_6, S_3 during 2019-20 and in pooled data and S_4 treatment too during 2020-21. The lower potassium availability was documented with S_2 followed by S_1. Similar findingss were also observed in earlier studies conducted by Mathew and Varughese (2007) and Kumar (2012). Application of higher level of K fertilizers could be the reason for higher residual K in soil after harvest of seed crop.

Plant nutrition uptake

N, P and K uptake (kg ha^{-1})

The biofertilizer applied plots recorded higher N, P and K uptake could be due to *Azospirillum* inoculation that fixes the atmospheric nitrogen and also synergistic effect of inoculated *Azospirillum* and PSB (Babu, 2009). In addition to this application of organics hinders the precipitation and fixation of phosphorus and retained it in soluble form thereby more availability of P resulting in higher absorption by plants. The symbiotic association between AM fungi and plants can produce colonies beyond root zone thereby more uptake of water and nutrients by plant roots besides acting as agent which can improve plant-water relationship through increased stomatal resistance by adjusting plant hormonal balance (Mulyani *et al*., 2017).

Higher nitrogen uptake with higher fertilizer doses could be due to application of nutrients which increased the nitrogen, phosphorus and potassium content in seedcane by providing balanced nutritional environment inside the plant thereby increased photosynthetic efficiency which resulted in more drymatter accumulation which inturn lead to higher uptake of N by seed crop.

Soil N, P and K availability

The improved N, P and K availability in soil with the application of biofertilisers and trash mulch might be due to FYM integrated biofertilisers release organic acids which solubilise the soil nutrient reserve besides ameliorating effect of trash rich in nutrient content fortified with lignified compounds present in organic manures are responsible for slow release of nutrients thereby reduced losses and buildup of soil N pool (Tyagi *et al*., 2011). Increased PSB activity in the rhizosphere owing to PSB application which constitute increased P solubilisation resulting in more available P in soil at appropriate growth stages (Sundara *et al*., 2002).

The treatment S_5 registered higher N, P and K availability in soil might result from increase in N fertilizer level assured increased availability of N to the sugarcane in adequate amount and leftover in soil in considerable amount after fulfilling the sugarcane needs that ultimately increased the post-harvest availability of N in soil (Kumar, 2012).

CONCLUSION

From this experiment, it can be concluded that availability of N, P and K in soil after crop harvest and uptake by seed cane were higher with the integration of biofertilisers or trash mulch coupled with 125% STBNK by composting waste and adding fertiliser to maintain soil fertility through biological recycling of nutrients in a sustainable manner.

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