INFLUENCE OF PLANT GEOMETRY AND INTERCROPPING ON SOIL FERTILITY AND NUTRIENT BUDGETING UNDER SUSTAINABLE SUGARCANE INITIATIVE PLANTING OF SUGARCANE (*SACCHARUM OFFICINARUM* L.) IN INDIA

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Abstract. Field experiments were conducted at Sugarcane Research Station, Tamil Nadu Agricultural University, Tamil Nadu during 2016-17 and 2017-18. The experiments were laid out the strip plot design with three replications. Among the different crop geometries, sugarcane double planting at 150 cm registered significantly higher available N, P and K in the post harvest soil which was closely followed by those at 150 cm in single row. With respect to different intercropping systems, higher available NPK was recorded under sugarcane + sunn hemp intercropping. The treatment combination of 150 cm double row planting with sunn hemp as intercrop recorded higher soil available P. The result of nutrient balance studies revealed sugarcane planting in double row at 150 cm crop geometry along sunn hemp as a planting system more favorable for the restoration of soil fertility where in higher net available N and P was observed. The results of the experiments revealed that double row planting of sugarcane at 150 cm spacing with *in-situ* incorporation of sunn hemp on 45th DAS increased the nutrient availability and maintained soil fertility of plant- ratoon sugarcane agroecosystem under tropical Indian conditions.
Keywords: *sustainable sugarcane initiative (SSI), plant geometry, intercropping, soil fertility and nutrient budgeting*

Introduction

Seed material, water and fertilizers are the important inputs for sugarcane production. Sustainable Sugarcane Initiative (SSI) is a method of sugarcane production which involves use of less seed materials, water and optimum fertilizers to achieve higher yields. Among the various irrigation methods, surface drip irrigation is the most efficient method for enhancing the input use efficiency of both water and nutrients. SSI under surface drip fertigation system can improve the water and nutrient use efficiency. Maintaining optimum plant population with suitable crop geometry is an important factor for sustained cane production and introduction of mechanization.

Significant differences in the uptake of N, P and K due to influence of various row spacing's and intercrops were observed by More (2003). The uptake of nutrients also differed significantly and it was higher in paired row planting (150 cm) than single row planting (270 cm) of sugarcane. Patel et al. (2014) observed that the planting geometries had significant influence on nutrient content in sugarcane plant and nutrient status of soil after harvest, while, uptake of nutrients by sugarcane were higher under 60-120-

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60 cm paired row planting compared to normal 90 cm and 120 cm twin row planting geometries. In the context of sugarcane mechanization, the SSI method of sugarcane planting is gaining more significance under tropical Indian sugarcane farming; however, the information on suitable crop geometries benefitting for the intercrop to restore the depleting soil health of plant-ratoon sugarcane agroecosystem is lacking.

With this background, the present field experiment was conducted to assess the nutrient budgeting and soil fertility status under different plant geometry and intercropping under sustainable sugarcane initiative.

Materials and methods

Field experiments were laid out during *special* seasons of 2016-17 and 2017-18 at Sugarcane Research Station, Tamil Nadu Agricultural University (TNAU), Sirugamani, located at Cauvery delta zone of Tamil Nadu. The geographical location of the experiment site is 10° 56'N latitude and 78° 26'E longitude with an altitude of 78.12 m above the MSL. The farm receives an average rainfall of 730.3 mm. The soil of the experimental site was well drained clay loam in texture with low in available nitrogen, medium in available phosphorus and high in available potassium. The initial soil status showed 234, 15.8 and 467 kg/ha of $KMnO_4$-N, Olsen P and NH_4OAc-K, respectively. The soil EC (0.29 dsm^{-1}) pH (8.58) and organic carbon (0.58%) indicated fairly suitable soil for the growth sugarcane crop. The experiments were laid out in strip plot design (SPD) with four treatments in main plot and four treatments in sub plot replicated thrice. The net plot size adopted was 27.0 m^2 (9.0 m × 3.0 m). Short duration pulses of green gram (ADT 3), black gram (VBN5) and sunn hemp (CO1) maturing in 60-75 days were used for the study. The main plot treatments comprised of crop geometry *viz.*, M_1- 150 × 60 cm Single row planting, M_2-150 × 60 cm Double row planting, M_3- 180 × 60 cm Single row planting and M_4-180 × 60 cm Double row planting (*Table 1*). The subplot treatments were S_1-Sole crop of Sugarcane, S_2-Sugarcane + Green gram, S_3-Sugarcane + Black gram and S_4-Sugarcane + Sunn hemp. The intercrops were raised in additive series *viz*., 3 rows under a row spacing of 150 cm in sugarcane and 4 rows under 180 cm (*Fig. 1*). The recommended schedule of drip fertigation for SSI was followed under surface drip irrigation system. The recommended dose followed was 300:100:200 kg/NPK/ha^{-1}. No additional fertilizers were applied to the intercrops.

Table 1. *Number of bud chip settling used per hectare in different crop geometries*

Different crop geometries adopted for SSI planting method			
Single row planting		**Double row planting**	
150 cm × 60 cm	180 cm × 60 cm	150 cm × 60 cm	180 cm × 60 cm
11,111	9,260	22,222	18,520

Post-harvest soil samples after the harvest of plant crop and ratoon crop were collected plot wise from a depth of 0-20 cm. The soil samples collected by using screw augur were air dried, powdered and passed through a 2 mm sieve and stored in clean polythene bags. The samples thus collected and processed were used for the determination of available nitrogen, phosphorus and potassium (kg ha^{-1}).

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The net gain in available nitrogen, phosphorus and potassium (kg ha^{-1}) was calculated using the corresponding available nutrient status at the beginning and at the end of the specific period (Sadanandan and Mahapatra, 1973).

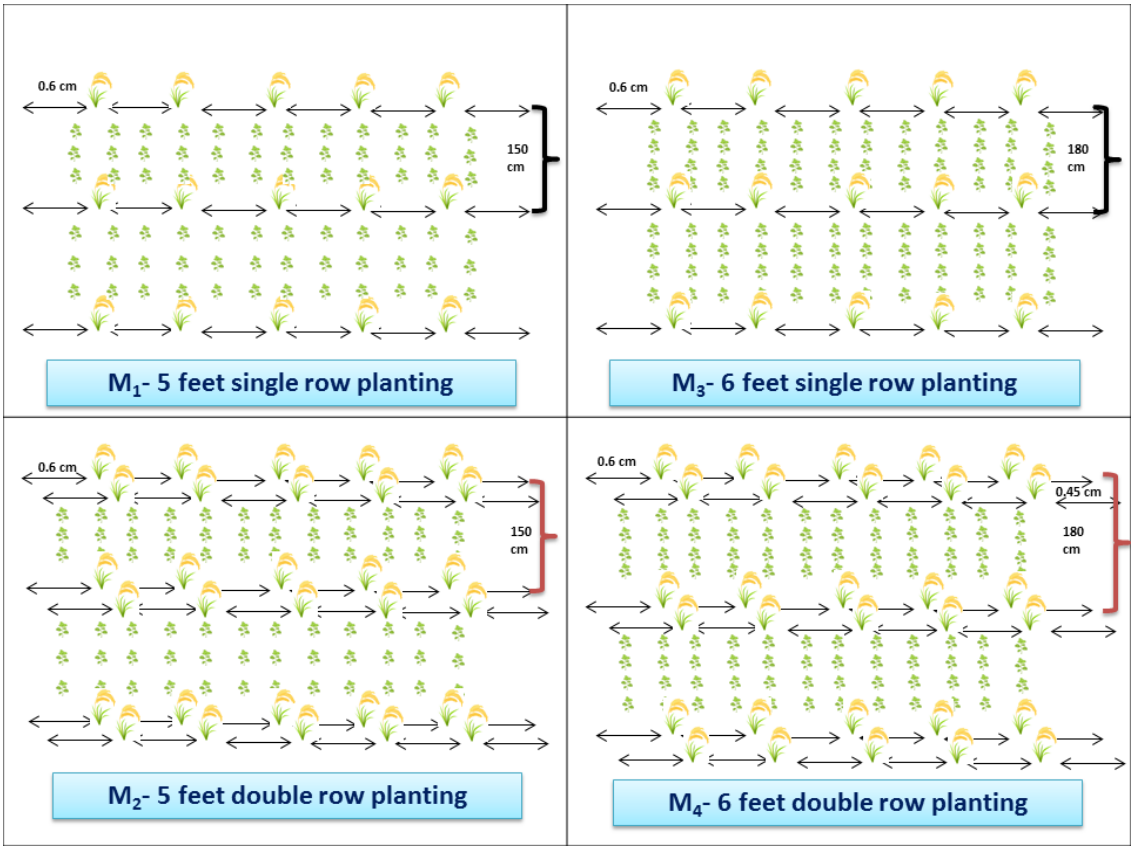

Figure 1. *Diagram for plant geometry (single and double row planting)*

Results

Influence of spacing and row arrangement and intercropping systems on soil available nitrogen of sugarcane

In plant crop (2016-17), among the planting rows, even though 180 cm double row planting (M_4) recorded higher available nitrogen 193.9 kg/ha, the difference between the treatments did not reach the level of significance (*Table 2*). With regard to intercropping systems, sugarcane with sunn hemp (S_4) recorded significantly higher nitrogen than other intercropping systems which were comparable among themselves. The interaction between crop geometries and intercropping systems under SSI planting method on available nitrogen was not significant during the plant crop.

In ratoon crop, among the crop geometries rows, even though 180 cm single row planting (M_3) recorded higher available nitrogen, the difference between the treatments did not reach the level of significance. With regard to intercropping systems, sugarcane with sunn hemp (S_4) recorded significantly higher nitrogen than the other intercropping systems which were comparable among themselves. The interaction between crop geometries and intercropping systems under SSI practices on available nitrogen was not significant in the ratoon crop.

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Table 2. *Influence of spacing and row arrangement and intercropping systems on soil available nitrogen (kg/ha) of sugarcane*

Treatment	Plant crop (2016-17)					Ratoon crop (2017-18)				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	173.0	170.0	180.0	175.8	**174.7**	184.9	180.2	190.9	185.9	**185.4**
S_2	170.0	168.0	170.0	173.0	**170.2**	180.7	178.2	185.7	181.9	**181.6**
S_3	168.0	165.0	160.0	170.0	**165.7**	179.8	177.9	183.8	180.8	**180.6**
S_4	250.8	250.0	258.0	257.0	**253.9**	280.0	280.0	290.7	289.9	**285.1**
Mean	**190.4**	**188.2**	**192.0**	**193.9**		**206.3**	**204.1**	**212.8**	**209.6**	
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SEd	2.7	3.9	7.9	8.4		3.1	6.9	8.9	10.9	
CD (P = 0.05)	NS	9.5	NS	NS		NS	17.1	NS	NS	

Main plot	Spacing and row arrangement	Sub plot	Intercropping systems
M_1	150 × 60 cm Single row planting	S_1	Sole crop of sugarcane
M_2	150 × 60 cm Double row planting	S_2	Sugarcane + Green gram
M_3	180 × 60 cm Single row planting	S_3	Sugarcane + Black gram
M_4	180 × 60 cm Double row planting	S_4	Sugarcane + Sunn hemp

Influence of spacing and row arrangement and intercropping systems on soil available phosphorus of sugarcane

In plant crop, among the planting rows, 180 cm single row planting recorded significantly higher phosphorus 34.36 kg/ha followed by 180 cm double rows. Planting at 150 cm in double rows recorded the lower phosphorus (*Table 3*). With regard to intercropping systems, sugarcane with sunn hemp (S_4) recorded higher available phosphorus followed by the other systems which were comparable among themselves. The interaction effects were significant wherein, the treatment combinations, sugarcane planted at 180 cm in single row with sunn hemp (M_3S_4) recorded higher available phosphorus. All the treatment combinations involving planting at 150 cm in single row (M_2S_3) recorded lower available phosphorus. Similar trends were also observed in ratoon crop also.

Influence of spacing and row arrangement and intercropping systems on soil available potassium of sugarcane

Marginally higher available potassium was recorded among the crop geometries i.e. planting at 180 cm single row (M_3) (587.8 kg/ha) and 180 cm double row (M_4) than 150 cm in double row (M_2) during 2016-17 in plant sugarcane crop (*Table 4*). With regard to intercropping systems, sugarcane with sunn hemp (S_4) recorded significantly higher (623.5 kg ha^{-1}) available potassium which was closely followed by sole crop of sugarcane (S_1) whereas; other systems were found comparable to sugarcane with sunn hemp.

In ratoon crop, planting at 180 cm single row planting (M_3) recorded higher potassium over the rest of crop geometries. With regard to intercropping systems, sugarcane with sunn hemp (S_4) recorded higher available potassium followed by the

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other systems which were comparable among themselves. Lower potassium recorded at sugarcane with black gram (S_3). The interaction effects were absent during plant and ratoon crop.

Table 3. *Influence of spacing and row arrangement and intercropping systems on soil available phosphorus (kg/ha) of sugarcane*

Treatment	Plant crop (2016-17)					Ratoon crop (2017-18)				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	27.90	23.10	32.80	30.72	**28.63**	25.00	20.99	33.00	29.00	**27.00**
S_2	26.90	21.10	31.81	29.91	**27.43**	23.90	20.15	31.72	27.71	**25.87**
S_3	24.51	19.88	30.71	28.00	**25.78**	22.81	18.23	30.83	26.88	**24.69**
S_4	47.53	45.88	50.50	48.80	**48.18**	62.82	60.00	65.10	64.00	**62.98**
Mean	**31.71**	**27.49**	**36.46**	**34.36**		**33.63**	**29.84**	**40.16**	**36.90**	
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SEd	0.84	0.44	1.19	0.95		0.65	0.59	1.29	1.26	
CD (P = 0.05)	2.05	1.08	2.70	2.07		1.60	1.45	2.82	2.74	

Main plot	Spacing and row arrangement	Sub plot	Intercropping systems
M_1	150 × 60 cm Single row planting	**S_1**	Sole crop of sugarcane
M_2	150 × 60 cm Double row planting	**S_2**	Sugarcane + Green gram
M_3	180 × 60 cm Single row planting	**S_3**	Sugarcane + Black gram
M_4	180 × 60 cm Double row planting	**S_4**	Sugarcane + Sunn hemp

Table 4. *Influence of spacing and row arrangement and intercropping systems on soil available Potassium (kg/ha) of sugarcane*

Treatment	Plant crop (2016-17)					Ratoon crop (2017-18)				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	568.9	565.9	575.8	573.9	**571.1**	542.8	538.8	555.8	548.2	**546.4**
S_2	565.8	563.8	572.8	572.8	**568.8**	541.9	535.2	553.9	547.8	**544.7**
S_3	564.8	561.8	573.7	570.2	**567.6**	540.8	533.2	551.8	546.7	**543.1**
S_4	620.8	618.8	628.9	625.7	**623.5**	665.1	650.1	660.2	658.4	**658.5**
Mean	**580.0**	**577.6**	**587.8**	**585.6**		**572.6**	**564.3**	**580.4**	**575.3**	
	M	**S**	**M at S**	**S at M**		**M**	**S**	**M at S**	**S at M**	
SEd	18.6	9.1	26.8	21.3		3.1	9.0	18.3	20.2	
CD (P = 0.05)	NS	22.2	NS	NS		7.7	22.1	NS	NS	

Main plot	Spacing and row arrangement	Sub plot	Intercropping systems
M_1	150 × 60 cm Single row planting	S_1	Sole crop of sugarcane
M_2	150 × 60 cm Double row planting	S_2	Sugarcane + Green gram
M_3	180 × 60 cm Single row planting	S_3	Sugarcane + Black gram
M_4	180 × 60 cm Double row planting	S_4	Sugarcane + Sunn hemp

Influence of spacing and row arrangement and intercropping systems on soil available N balance of sugarcane

Inplant crop (2016-17), the net gain in soil available N was higher with 180 cm single row intercropped with sunn hemp (M_3S_4) which was followed by 180 cm double

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rows with sunn hemp (M_4S_4). A net loss of 39 kg ha^{-1} of soil available N was observed with 180 cm single row planting with black gram (M_3S_3). This was followed by 150 cm double rows with black gram (M_2S_3) (*Tables 5* and *6*). The similar trends with respect to available soil N balance were also recorded in ratoon crop.

Influence of spacing and row arrangement and intercropping systems on soil available P balance of sugarcane

In most of the treatment combinations, both positive as well the negative soil available P trend was observed during plant crop, The net gain in respect of soil available P was higher with 180 cm single row intercropped with sunn hemp (M_3S_4) which was closely followed by 180 cm double rows with sunn hemp (M_4S_4). A net loss of 24 kg ha^{-1} of soil available P was observed under sugarcane planted at 150 cm in double rows with black gram (M_2S_3) which was followed by 150 cm double rows with green gram (M_2S_2) (*Tables 7* and *8*). Similar trends were also registered in ratoon crop during second year of experimentation.

Table 5. *Influence of spacing and row arrangement and intercropping systems on soil available N balance of sugarcane plant crop (2016-17)*

Treatment	Initial soil N (kg/ha) A	Total N applied (kg/ha) B	Plant uptake (kg/ha) C	Expected balance D = (a + b)-c	Post harvest soil N (kg/ha) E	Computed balance (kg/ha)	Net gain or loss (kg/ha)
M_1S_1	199	300	399	100	173	-99	-26
M_1S_2	199	300	402	97	170	-102	-29
M_1S_3	199	300	414	85	168	-114	-31
M_1S_4	199	300	421	78	251	-121	52
M_2S_1	199	300	427	72	170	-127	-29
M_2S_2	199	300	433	66	168	-133	-31
M_2S_3	199	300	466	33	165	-166	-34
M_2S_4	199	300	491	8	250	-191	51
M_3S_1	199	300	364	135	180	-64	-19
M_3S_2	199	300	363	136	170	-63	-29
M_3S_3	199	300	376	123	160	-76	-39
M_3S_4	199	300	390	109	258	-90	59
M_4S_1	199	300	382	117	176	-82	-23
M_4S_2	199	300	390	109	173	-90	-26
M_4S_3	199	300	405	94	170	-105	-29
M_4S_4	199	300	373	126	257	-73	58

			SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M	Standard value	Standard value	7.0	17.1	2.36	5.70	2.7	NS	1.31	3.21	0.91	2.22
S			4.4	10.8	1.64	4.03	3.9	9.5	1.80	4.41	0.85	2.09
M at S			11.4	25.6	3.65	8.26	7.9	NS	3.80	8.14	1.44	3.23
S at M			10.1	21.9	3.26	7.15	8.4	NS	3.99	8.68	1.40	3.14

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Table 6. *Influence of spacing and row arrangement and intercropping systems on soil available N balance of sugarcane Ratoon crop (2017-18)*

Treatment	Initial soil N (kg/ha) A		Total N applied (kg/ha) B	Plant uptake (kg/ha) C		Expected balance D = (a + b)-c		Post harvest soil N (kg/ha) E		Computed balance (kg/ha)		Net gain or loss (kg/ha)	
M_1S_1	173		325	399		99		185		-74		12	
M_1S_2	170		325	409		86		181		-84		11	
M_1S_3	168		325	420		73		180		-95		12	
M_1S_4	251		325	432		144		280		-107		29	
M_2S_1	170		325	443		52		180		-118		10	
M_2S_2	168		325	466		27		178		-141		10	
M_2S_3	165		325	486		4		178		-161		13	
M_2S_4	250		325	547		28		280		-222		30	
M_3S_1	180		325	349		156		191		-24		11	
M_3S_2	170		325	349		146		186		-24		16	
M_3S_3	160		325	354		131		184		-29		24	
M_3S_4	258		325	380		203		291		-55		33	
M_4S_1	176		325	382		119		186		-57		10	
M_4S_2	173		325	387		111		182		-62		9	
M_4S_3	170		325	398		97		181		-73		11	
M_4S_4	257		325	415		167		290		-90		33	
	SEd	**CD**		**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**
M	2.7	NS	Standard value	**8.9**	**22.0**	1.57	3.84	3.1	NS	2.29	5.62	0.37	0.91
S	3.9	9.5		5.3	12.9	2.38	5.83	6.9	17.09	1.35	3.31	0.73	1.79
M at S	7.9	NS		14.6	32.5	3.24	7.05	8.9	NS	3.86	8.59	0.82	1.78
S at M	8.4	NS		12.6	27.3	3.69	8.30	10.9	NS	3.39	7.32	1.03	2.35

Influence of spacing and row arrangement and intercropping systems on soil available K balance of sugarcane

In plant crop, lower K loss was observed under single row planting of sugarcane + sunn hemp at crop geometry of 180 cm (M_2S_4) which was followed by 180 cm double row intercropped with sunn hemp (M_2S_4). Higher K loss (-111 kg ha^{-1}) was recorded under the treatment combination of sugarcane planted at 150 cm in double rows (M_2S_3) (*Tables 9* and *10*).

In ratoon crop (2017-18), the net gain in respect of soil available K was higher with 150 cm single row intercropped with sunn hemp (M_1S_4) which was closely followed by 180 cm double rows with sunn hemp (M_4S_4). A net loss of (-29 kg ha^{-1}) of soil available K was observed in 180 cm double rows with black gram (M_2S_3) which was followed by 180 cm double rows with green gram (M_2S_2).

Discussion

Post-harvest soil available nutrients NPK

Soil fertility was quantified with available N, P and K in soil. Adequate supply of nutrients would satisfy nutrient demand of crop besides improving the soil fertility. In

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2016-17 and 2017-18 plant crop and ratoon crop among the planting rows, 180 cm double row planting (M_4) recorded higher concentration of available NPK which was closely followed by 180 cm double row planting (M_3).

Table 7. *Influence of spacing and row arrangement and intercropping systems on soil available P balance of sugarcane plant crop (2016-17)*

Treatment	Initial soil P (kg/ha) A	Total P applied (kg/ha) B	Plant uptake (kg/ha) C	Expected balance D = (a + b)-c	Post harvest soil P (kg/ha) E	Computed balance (kg/ha)	Net gain or loss (kg/ha)
M_1S_1	44	100	75	69	28	26	-16
M_1S_2	44	100	75	69	27	25	-17
M_1S_3	44	100	76	68	25	24	-19
M_1S_4	44	100	79	65	48	21	4
M_2S_1	44	100	83	61	23	17	-21
M_2S_2	44	100	85	60	21	16	-23
M_2S_3	44	100	85	59	20	15	-24
M_2S_4	44	100	96	48	46	4	2
M_3S_1	44	100	68	76	33	32	-11
M_3S_2	44	100	70	74	32	30	-12
M_3S_3	44	100	70	74	31	30	-13
M_3S_4	44	100	73	71	51	27	7
M_4S_1	44	100	74	71	31	27	-13
M_4S_2	44	100	75	69	30	25	-14
M_4S_3	44	100	75	69	28	25	-16
M_4S_4	44	100	77	67	49	23	5

			SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M	Standard value	Standard value	1.52	3.72	1.35	3.31	0.84	2.05	0.44	1.09	0.14	0.34
S			1.17	2.86	1.36	3.35	0.44	1.08	0.33	0.81	0.17	0.43
M at S			1.94	4.49	2.95	6.42	1.19	2.70	0.70	1.58	0.44	0.95
S at M			1.68	3.81	2.96	6.44	0.95	2.07	0.64	1.40	0.45	0.98

The intercropping systems, sugarcane with sunn hemp (S_4) recorded significantly higher NPK than the other intercropping system of sugarcane with black gram. Sunn hemp plant was succulent enough and easily decomposable, which accumulated 133 kg N ha^{-1} as reported by Sanya siraju (1952). The increase in soil available nutrients with result of daincha incorporation was very well documented by Swarup (1991) who reported that green manuring with daincha improved the available N in soil throughout the profile compared to initial status. The author was also of the opinion that the P availability improved due to greater mobilization of native soil P compounds by vigorous daincha root system and added biomass. Similar findings were made out by Yadav (1984), Jadhav (1996) and Nasir Ahmed (1999). Two rows of daincha incorporated on 45 DAP registered higher post-harvest soil nutrients followed by other systems as per the findings reported by Guru (1997).

The sugarcane with sunn hemp (S_4) recorded significantly higher available nitrogen, phosphorus and potassium which were followed by sole crop of sugarcane (S_1),

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sugarcane + green gram and sugarcane + black gram intercropping. This may be attributed to incorporation of green manure sunn hemp in sugarcane on 45th day which lead to significant higher available NPK.

Growing of green manures in the inter row spacing and incorporation at appropriate time not only fulfill crop nutrient requirement but also maintain soil fertility. Since, sugarcane produces heavy biomass during its ontogeny and it requires high amount of Nitrogen. To meet the increasing nitrogen demand of sugarcane crop, the practice of green manuring coupled with nitrogen application found highly beneficial (Guru, 1997). Improved available soil nitrogen status due to growing of Sesbania *aculeata* and its *in situ* soil incorporation was also reported by Venkatakrishnan (1980).

Results of experimental findings of Shankaraiah et al. (1999) on intercropping and incorporation of legume have established the beneficial effect of increased NUE in sugarcane. Similarly, sunn hemp intercropping and its in *situ* soil incorporation on 45thdays after planting of sugarcane also increased availability plant nutrients like NPK and organic carbon content (Jayapaul et al. 2000).

Talashiltar and Patil (1979) and Ghosh et al. (1981) reported the production of phenolic and aliphatic acids during decomposition of organic matter and thereby solubilized appreciable amount of phosphates resulting in increased P availability in soil. *Sesbania aculeate* increased the microbial population of soil and thus enhanced mineralization of soil and other essential nutrients Khind and Maskina (1986).

Table 8. *Influence of spacing and row arrangement and intercropping systems on soil available P balance of sugarcane Ratoon crop (2017-18)*

Treatment	Initial soil P (kg/ha) A		Total P applied (kg/ha) B	Plant uptake (kg/ha) C		Expected balance D = (a + b)-c		Post harvest soil P (kg/ha) E		Computed balance (kg/ha)		Net gain or loss (kg/ha)	
M_1S_1	28		100	71		57		25		29		-3	
M_1S_2	27		100	71		56		24		29		-3	
M_1S_3	25		100	71		54		23		29		-2	
M_1S_4	48		100	74		74		63		26		15	
M_2S_1	23		100	76		47		21		24		-2	
M_2S_2	21		100	76		45		20		24		-1	
M_2S_3	20		100	77		43		18		23		-2	
M_2S_4	46		100	90		56		60		10		14	
M_3S_1	33		100	64		69		33		36		0	
M_3S_2	32		100	64		68		32		36		0	
M_3S_3	31		100	65		66		31		35		0	
M_3S_4	51		100	70		81		65		31		15	
M_4S_1	31		100	67		64		29		33		-2	
M_4S_2	30		100	67		63		28		33		-2	
M_4S_3	28		100	68		60		27		32		-1	
M_4S_4	49		100	72		77		64		28		15	
	SEd	**CD**		**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**
M	0.84	2.05	Standard value	1.24	3.04	1.37	3.37	0.65	1.60	0.48	1.19	0.18	0.44
S	0.44	1.08		1.19	2.90	0.64	1.58	0/59	1.45	0.52	1.28	0.24	0.59
M at S	1.19	2.70		1.92	4.31	2.22	4.97	1.29	2.82	0.98	2.14	0.38	0.84
S at M	0.95	2.07		1.89	4.22	1.86	3.98	1.26	2.74	1.0	2.20	0.42	0.93

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Table 9. *Influence of spacing and row arrangement and intercropping systems on soil available K balance of sugarcane plant crop (2016-17)*

Treatment	Initial soil K (kg/ha) A	Total K applied (kg/ha) B	Plant uptake (kg/ha) C	Expected balance D = (a + b)-c	Post harvest soil K (kg/ha) E	Computed balance (kg/ha)	Net gain or loss (kg/ha)
M_1S_1	676	200	488	388	569	-288	-107
M_1S_2	676	200	489	387	566	-289	-110
M_1S_3	676	200	490	386	565	-290	-111
M_1S_4	676	200	530	346	621	-330	-55
M_2S_1	676	200	519	357	566	-319	-110
M_2S_2	676	200	520	356	564	-320	-112
M_2S_3	676	200	520	356	562	-320	-114
M_2S_4	676	200	598	278	619	-398	-57
M_3S_1	676	200	469	407	576	-269	-100
M_3S_2	676	200	470	406	573	-270	-103
M_3S_3	676	200	470	406	574	-270	-102
M_3S_4	676	200	490	386	629	-290	-47
M_4S_1	676	200	486	390	574	-286	-102
M_4S_2	676	200	487	389	573	-287	-103
M_4S_3	676	200	490	386	570	-290	-106
M_4S_4	676	200	520	356	626	-320	-50

			SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M	Standard value	Standard value	7.4	18.2	6.85	16.76	18.6	NS	3.87	9.47	2.18	5.35
S			2.7	6.6	7.10	17.39	9.1	22.2	7.15	17.51	2.34	5.74
M at S			10.8	24.4	15.83	34.29	26.8	NS	10.50	22.57	3.35	7.53
S at M			8.2	17.6	15.94	34.60	21.3	NS	12.11	26.90	3.45	7.81

Suitability of Prickly sesban or local daincha *(Sesbania aculeata* L.), African daincha *(Sesbania rostrata* L.), indigo *(Indigofera tintoria* L.) and sunn hemp *(Crotolaria juncea* L.) as a green manuring crops due to their fast growth habits was reported by Alam et al. (1997). The total N and availability of P and K of soil also increased slightly after use of green manures. Kormilitsyn (1995) reported that the green manure had the greatest effect on crop productivity. However, the increase in yield depends upon the quantity of organic matter and N, soil ploughed in the results of the above scientists lead support to the present findings.

Soil available nutrient balance NPK

Different crop geometries and legume-based intercropping in sugarcane increased soil available nutrient balance during the sugarcane plant and ratoon crop cycle of our experimentations. The post- harvest soil nutrient balance was found positive and indicated a net gain due to legume-based intercropping in sugarcane. Further, the mineralization of green manures and release pattern of nutrients into soil solution differs largely and accordingly, the final balance of soil organic carbon and available NPK reflected source-wise.

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Table 10. *Influence of spacing and row arrangement and intercropping systems on soil available K balance of sugarcane Ratoon crop (2017-18)*

Treatment	Initial soil K (kg/ha) A		Total K applied (kg/ha) B	Plant uptake (kg/ha) C		Expected balance D = (a + b)– c		Post harvest soil K (kg/ha) E		Computed balance (kg/ha)		Net gain or loss (kg/ha)	
M_1S_1	569		200	519		250		543		-319		-26	
M_1S_2	566		200	519		247		542		-319		-24	
M_1S_3	565		200	520		245		541		-320		-24	
M_1S_4	621		200	530		291		665		-330		44	
M_2S_1	566		200	525		241		539		-325		-27	
M_2S_2	564		200	525		239		535		-325		-29	
M_2S_3	562		200	525		237		533		-325		-29	
M_2S_4	619		200	600		219		650		-400		31	
M_3S_1	576		200	468		308		556		-268		-20	
M_3S_2	573		200	469		304		554		-269		-19	
M_3S_3	574		200	470		304		552		-270		-22	
M_3S_4	629		200	485		344		660		-285		31	
M_4S_1	574		200	517		257		548		-317		-26	
M_4S_2	573		200	518		255		548		-318		-25	
M_4S_3	570		200	519		251		547		-319		-23	
M_4S_4	626		200	528		298		658		-328		33	
	SEd	**CD**		**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**	**SEd**	**CD**
M	18.6	NS	Standard value	5.7	13.9	6.69	16.38	3.1	7.7	5.48	13.41	0.35	0.87
S	9.1	22.2		5.0	12.3	4.11	10.06	9.0	22.1	5.25	12.86	0.39	0.96
M at S	26.8	NS		12.4	27.1	12.57	27.65	18.3	NS	13.79	29.72	0.68	1.50
S at M	21.3	NS		12.1	26.3	11.41	24.45	20.2	NS	13.70	29.48	0.70	1.55

At the end of the plant –ratoon crop cycle, there was no appreciable net gain of nitrogen under different crop geometries with sole crop of sugarcane, which again proved that sugarcane is an exhaustive crop wherein absorption of nutrient depleted the native soil nutrient pool increasingly and moreover the weed competition accelerated the nutrient depletion to greater extent by sole sugarcane. Whereas, double row planting of sugarcane with sunn hemp intercrop showed positive balance of nitrogen, indicating the overall net gain. The increased nutrient indices under sunn hemp intercropping were due to increased availability of plant nutrients owing to sunn hemp incorporation on 45 DAP and this is in conformity with findings of Swarup (1991) and Guru (1997). Neelima and Bhanu murthy (2009) reported that soil nitrogen balance was positive under incorporation of total plant (16 kg N/ha) or shoot (11 kg N/ha) of sunn hemp green manure and also with the application of 120 (1 kg N/ha) and 180 kg (19 kg N/ha).

Net gain of available P was realized under different crop geometries and intercropping systems during both plant and ratoon crops (2016 to 2017).

The negative and positive potassium (K) balance was noticed under the treatment combination of various crop geometries and intercropping systems. Lesser negative balance was observed in crop geometries with sunn hemp during the first plant crop, net gain K also observed under sugarcane with sunn hemp during the ratoon crop.

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Conclusion

From the results of the experiments, it could be concluded that double row planting of sugarcane at 150 cm spacing with *in-situ* incorporation of sunn hemp on45th DAS increased the nutrient availability and maintained soil fertility of plant- ratoon sugarcane agroecosystem under tropical Indian condition. Intercropping studies based different planting methods under sub surface drip fertigation. Intercropping studies on root systems stabilization in sugarcane by using subsurface drip fertigation methods.

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