

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-

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 KMnO₄-N, Olsen P and NH₄OAc-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 m² (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., M₁- 150 × 60 cm Single row planting, M₂-150 × 60 cm Double row planting, M₃- 180 × 60 cm Single row planting and M₄-180 × 60 cm Double row planting (*Table 1*). The subplot treatments were S₁-Sole crop of Sugarcane, S₂-Sugarcane + Green gram, S₃-Sugarcane + Black gram and S₄-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).

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).

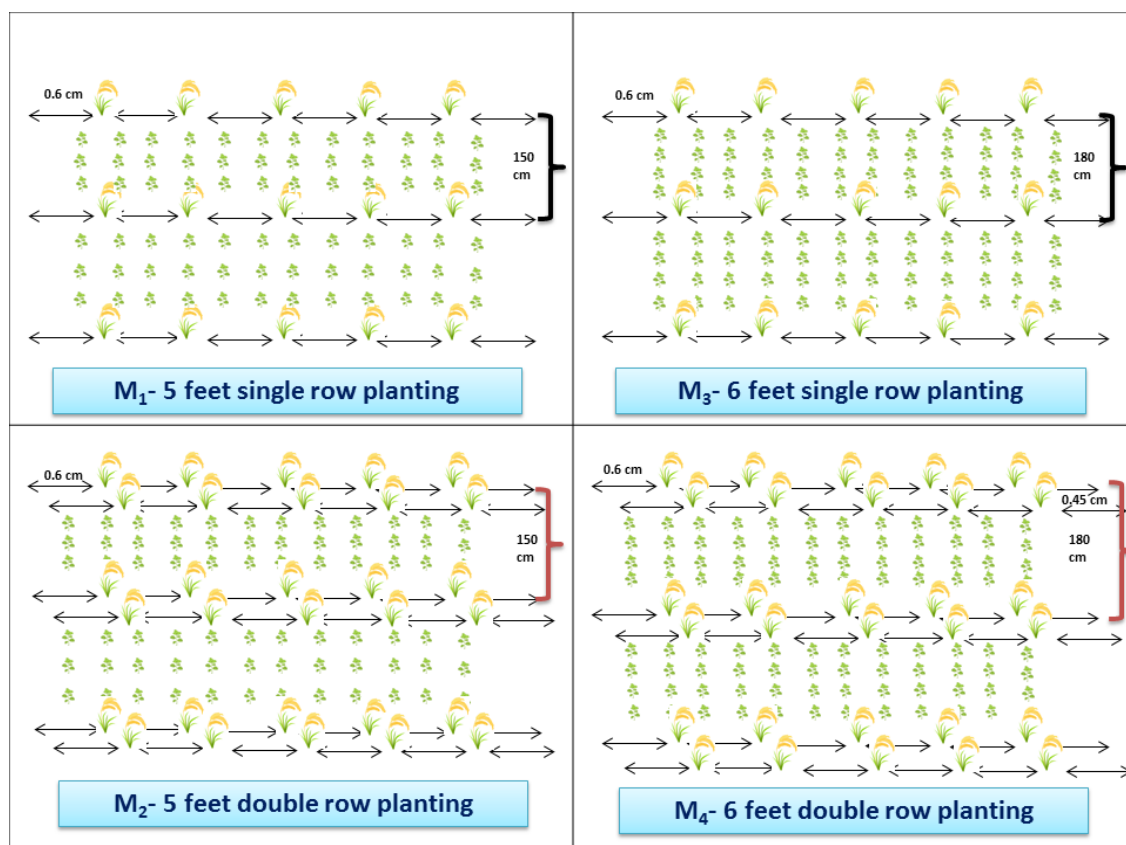


Figure 1. Diagram for plant geometry (single and double row planting)

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 (M₄) 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 (S₄) 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 (M₃) 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 (S₄) 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.

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 (S₄) 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 (M₃S₄) recorded higher available phosphorus. All the treatment combinations involving planting at 150 cm in single row (M₂S₃) 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 (M₃) (587.8 kg/ha) and 180 cm double row (M₄) than 150 cm in double row (M₂) during 2016-17 in plant sugarcane crop (Table 4). With regard to intercropping systems, sugarcane with sunn hemp (S₄) recorded significantly higher (623.5 kg ha⁻¹) available potassium which was closely followed by sole crop of sugarcane (S₁) whereas; other systems were found comparable to sugarcane with sunn hemp.

In ratoon crop, planting at 180 cm single row planting (M₃) recorded higher potassium over the rest of crop geometries. With regard to intercropping systems, sugarcane with sunn hemp (S₄) recorded higher available potassium followed by the

other systems which were comparable among themselves. Lower potassium recorded at sugarcane with black gram (S₃). 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 (M₃S₄) which was followed by 180 cm double

rows with sunn hemp (M₄S₄). A net loss of 39 kg ha⁻¹ of soil available N was observed with 180 cm single row planting with black gram (M₃S₃). This was followed by 150 cm double rows with black gram (M₂S₃) (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 (M₃S₄) which was closely followed by 180 cm double rows with sunn hemp (M₄S₄). 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 (M₂S₃) which was followed by 150 cm double rows with green gram (M₂S₂) (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 ₁ S ₁	199	300	399		100		173		-99		-26	
M ₁ S ₂	199	300	402		97		170		-102		-29	
M ₁ S ₃	199	300	414		85		168		-114		-31	
M ₁ S ₄	199	300	421		78		251		-121		52	
M ₂ S ₁	199	300	427		72		170		-127		-29	
M ₂ S ₂	199	300	433		66		168		-133		-31	
M ₂ S ₃	199	300	466		33		165		-166		-34	
M ₂ S ₄	199	300	491		8		250		-191		51	
M ₃ S ₁	199	300	364		135		180		-64		-19	
M ₃ S ₂	199	300	363		136		170		-63		-29	
M ₃ S ₃	199	300	376		123		160		-76		-39	
M ₃ S ₄	199	300	390		109		258		-90		59	
M ₄ S ₁	199	300	382		117		176		-82		-23	
M ₄ S ₂	199	300	390		109		173		-90		-26	
M ₄ S ₃	199	300	405		94		170		-105		-29	
M ₄ S ₄	199	300	373		126		257		-73		58	
	Standard value	Standard value	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M			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

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

Treat ment	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 ₁ S ₁	173		325	399		99		185		-74		12	
M ₁ S ₂	170		325	409		86		181		-84		11	
M ₁ S ₃	168		325	420		73		180		-95		12	
M ₁ S ₄	251		325	432		144		280		-107		29	
M ₂ S ₁	170		325	443		52		180		-118		10	
M ₂ S ₂	168		325	466		27		178		-141		10	
M ₂ S ₃	165		325	486		4		178		-161		13	
M ₂ S ₄	250		325	547		28		280		-222		30	
M ₃ S ₁	180		325	349		156		191		-24		11	
M ₃ S ₂	170		325	349		146		186		-24		16	
M ₃ S ₃	160		325	354		131		184		-29		24	
M ₃ S ₄	258		325	380		203		291		-55		33	
M ₄ S ₁	176		325	382		119		186		-57		10	
M ₄ S ₂	173		325	387		111		182		-62		9	
M ₄ S ₃	170		325	398		97		181		-73		11	
M ₄ S ₄	257		325	415		167		290		-90		33	
	SEd	CD	Standard value	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M	2.7	NS		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 (M₂S₄) which was followed by 180 cm double row intercropped with sunn hemp (M₂S₄). Higher K loss (-111 kg ha⁻¹) was recorded under the treatment combination of sugarcane planted at 150 cm in double rows (M₂S₃) (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 (M₁S₄) which was closely followed by 180 cm double rows with sunn hemp (M₄S₄). A net loss of (-29 kg ha⁻¹) of soil available K was observed in 180 cm double rows with black gram (M₂S₃) which was followed by 180 cm double rows with green gram (M₂S₂).

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

2016-17 and 2017-18 plant crop and ratoon crop among the planting rows, 180 cm double row planting (M₄) recorded higher concentration of available NPK which was closely followed by 180 cm double row planting (M₃).

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 ₁ S ₁	44	100	75	69		28		26		-16		
M ₁ S ₂	44	100	75	69		27		25		-17		
M ₁ S ₃	44	100	76	68		25		24		-19		
M ₁ S ₄	44	100	79	65		48		21		4		
M ₂ S ₁	44	100	83	61		23		17		-21		
M ₂ S ₂	44	100	85	60		21		16		-23		
M ₂ S ₃	44	100	85	59		20		15		-24		
M ₂ S ₄	44	100	96	48		46		4		2		
M ₃ S ₁	44	100	68	76		33		32		-11		
M ₃ S ₂	44	100	70	74		32		30		-12		
M ₃ S ₃	44	100	70	74		31		30		-13		
M ₃ S ₄	44	100	73	71		51		27		7		
M ₄ S ₁	44	100	74	71		31		27		-13		
M ₄ S ₂	44	100	75	69		30		25		-14		
M ₄ S ₃	44	100	75	69		28		25		-16		
M ₄ S ₄	44	100	77	67		49		23		5		
	Standard value	Standard value	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M			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 (S₄) 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 (S₄) recorded significantly higher available nitrogen, phosphorus and potassium which were followed by sole crop of sugarcane (S₁),

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 45th days 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 ₁ S ₁	28	100	71	57	25	29	-3						
M ₁ S ₂	27	100	71	56	24	29	-3						
M ₁ S ₃	25	100	71	54	23	29	-2						
M ₁ S ₄	48	100	74	74	63	26	15						
M ₂ S ₁	23	100	76	47	21	24	-2						
M ₂ S ₂	21	100	76	45	20	24	-1						
M ₂ S ₃	20	100	77	43	18	23	-2						
M ₂ S ₄	46	100	90	56	60	10	14						
M ₃ S ₁	33	100	64	69	33	36	0						
M ₃ S ₂	32	100	64	68	32	36	0						
M ₃ S ₃	31	100	65	66	31	35	0						
M ₃ S ₄	51	100	70	81	65	31	15						
M ₄ S ₁	31	100	67	64	29	33	-2						
M ₄ S ₂	30	100	67	63	28	33	-2						
M ₄ S ₃	28	100	68	60	27	32	-1						
M ₄ S ₄	49	100	72	77	64	28	15						
	SEd	CD	Standard value	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M	0.84	2.05		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

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 ₁ S ₁	676	200	488	388		569		-288		-107		
M ₁ S ₂	676	200	489	387		566		-289		-110		
M ₁ S ₃	676	200	490	386		565		-290		-111		
M ₁ S ₄	676	200	530	346		621		-330		-55		
M ₂ S ₁	676	200	519	357		566		-319		-110		
M ₂ S ₂	676	200	520	356		564		-320		-112		
M ₂ S ₃	676	200	520	356		562		-320		-114		
M ₂ S ₄	676	200	598	278		619		-398		-57		
M ₃ S ₁	676	200	469	407		576		-269		-100		
M ₃ S ₂	676	200	470	406		573		-270		-103		
M ₃ S ₃	676	200	470	406		574		-270		-102		
M ₃ S ₄	676	200	490	386		629		-290		-47		
M ₄ S ₁	676	200	486	390		574		-286		-102		
M ₄ S ₂	676	200	487	389		573		-287		-103		
M ₄ S ₃	676	200	490	386		570		-290		-106		
M ₄ S ₄	676	200	520	356		626		-320		-50		
	Standard value	Standard value	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M			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 tinctoria* L.) and sunn hemp (*Crotalaria 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.

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 ₁ S ₁	569		200	519		250		543		-319		-26	
M ₁ S ₂	566		200	519		247		542		-319		-24	
M ₁ S ₃	565		200	520		245		541		-320		-24	
M ₁ S ₄	621		200	530		291		665		-330		44	
M ₂ S ₁	566		200	525		241		539		-325		-27	
M ₂ S ₂	564		200	525		239		535		-325		-29	
M ₂ S ₃	562		200	525		237		533		-325		-29	
M ₂ S ₄	619		200	600		219		650		-400		31	
M ₃ S ₁	576		200	468		308		556		-268		-20	
M ₃ S ₂	573		200	469		304		554		-269		-19	
M ₃ S ₃	574		200	470		304		552		-270		-22	
M ₃ S ₄	629		200	485		344		660		-285		31	
M ₄ S ₁	574		200	517		257		548		-317		-26	
M ₄ S ₂	573		200	518		255		548		-318		-25	
M ₄ S ₃	570		200	519		251		547		-319		-23	
M ₄ S ₄	626		200	528		298		658		-328		33	
	SEd	CD	Standard value	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
M	18.6	NS		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.

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 on 45th 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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REFERENCES

- [1] Alam, F., Majid, M. A., Islam, M. J. (1997): Effect of biomanures on sugarcane. – Indian Journal of Agriculture Science 67(10): 450-455.
- [2] Ghosh, S. C., Omanwar, P. K., Sachan, R. S., Sharma, R. B. (1981): Reserves of organic and total phosphorus in cultivated and forested mouisols. – Indian Journal of Soil Science 29: 332-336.
- [3] Guru, G. (1997): Influence of population and stage of incorporation of intercropping of intercropped green manure (Daincha) and nitrogen levels on sugarcane. – M.Sc. (Agri.) Thesis, Tamil Nadu Agricultural University, Madurai.
- [4] Jadhav, S. B. (1996): Effect of incorporation of sugarcane trash on cane productivity and soil fertility. – In: Proceedings of 22nd Congress of the ISSTC held at Cartagena, Colombia, pp. 104-108.
- [5] Jayapaul, G. P., Duraisingh, R., Senthilvel, T., Joseph, M. (2000): Influence of population and stage of incorporation of intercropped green manure (daincha) and nitrogen levels on yield and quality of sugarcane. – Indian Sugar 51(2): 989-991.
- [6] Khind, C. S., Maskina, M. S. (1986): Effect of sesbania green manure on water management and yield of lowland rice. – International Rice Research Notes 11(5): 45.
- [7] Kormilitsyn, V. F. (1995): Agro-chemistry of green manuring in irrigated agriculture in the Volga region. Part 2. Agrochemical and Agro-ecological aspects of using sowings of annual legumes as green manure. – Agrokhimiya 77-93.
- [8] More, S. M. (2003): Study on effect of row spacing, planting system and intercropping on growth, yield and economics of *suru* sugarcane (Co 86032) and its ratoon under drip irrigation. – Ph. D. Thesis, MPKV, Rahuri.
- [9] Nasir Ahmed, S. (1999): Influence of sunn hemp intercropping in sugarcane. – Sugar Journal 24: 51-54.
- [10] Neelima, T. L., Bhanumurthy, V. B. (2009): Growth and yield attributes of rice as influenced by N fertilizer and differential incorporation of sunn hemp green manure. – Journal of Rice Research 2(1): 45-50.
- [11] Patel, D., Raj, V. C., Tandel, B. (2014): Study the influence of planting distance and variety on growth of sugarcane. – Journal of International Academic Research 2: 1092.
- [12] Sadanandan, N., Mahapatra, I. C. (1973): Studies on multiple cropping –balance of total and available phosphorus in various cropping pattern. – Indian Journal of Agronomy 18: 459-463.
- [13] Sanya Siraju, B. K. (1952): Companion cropping with autumn planted sugarcane. – Annual Report: Indian Institute Sugarcane Research, Lucknow, pp. 20-21.

- [14] Shankaraiah, C., Nagaraju, M. S., Usha Ravindra. (1999): Ways and means to improve fertilizer use efficiency in sugarcane. – Co-operative Sugar 30(10): 965-969.
- [15] Swarup, A. (1991): Long term effect of green manuring (*Sesbania aculeate*) on soil properties and sustainability of rice and wheat yield on sodic soil. – Indian Society Soil Science 27: 201-202.
- [16] Talashiltar, F. C., Patil, S. (1979): Effect of organic manures on the availability of phosphorus from single superphosphate and rock-phosphate. – Indian Journal of Soil Science 27: 201-202.
- [17] Venkatakrishnan, S. (1980): Mineralization of green manure (*Sesbania aculeate*), nitrogen in sodic and reclaimed soils under flooded conditions. – Plant and Soil 54: 149-152.
- [18] Yadav, R. L. (1984): Soil fertility in relation to crop yields of sugarcane based cropping systems in North Central India. – Journal Agronomy and Crop Science 153(5): 328-333.