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K Vaiyapuri
Professor of Agronomy, Department of Agronomy Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

S Selvakumar
Department of Agronomy Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

V Manivannan
Department of Agronomy Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

S Anbumani
Department of Agronomy Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Correspondence
K Vaiyapuri
Professor of Agronomy, Department of Agronomy Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Planting techniques in sugarcane as influenced by growth, yield and water productivity in western agro climatic zones of Tamil Nadu

K Vaiyapuri, S Selvakumar, V Manivannan and S Anbumani

Abstract
Field experiments were conducted at Western Agro Climatic Zone of Tamil Nadu during 2012 to 2014 in main and ratoon crops of sugarcane with an objective to increase the yield and productivity. The experiments comprised of 10 demonstrations in factory zone following two different methods of cultivation *viz.,* Sustainable Sugarcane Initiative methods (SSI) and Conventional System (CV).Each demonstration was conducted in large sized plots (0.40 ha) with sub surface drip irrigation. The results indicated higher plant height at harvest stage under SSI method (299 cm) compared to CV planting (262 cm). Other yield attributing characters *viz.,* number of inter nodes/plant, number of millable canes/clump, girth, individual cane weight (kg/cane) and cane yield were also higher under SSI method with increased gross income, net return and B: C ratio both in main crop and ratoon crop. It was further observed that the water consumption was less (1820 mm) and water productivity was more (7.61 kg m^{-3}) in SSI method compared to conventional planting (1927 mm and 5.82 kg m^3 water consumption and water productivity, respectively).

Keywords: Drip irrigation, Chip budded seedlings, sustainable sugarcane Initiative

Introduction
Sugarcane (*Saccharum officinarum*) is an important commercial crop and there are 50 million sugarcane farmers in India. Another 5 million people depend on employment generated by 571 sugar factories and related industries in this country. In Uttar Pradesh, Maharashtra and Tamil Nadu, sugarcane plays a major role in the state economy. Uttar Pradesh has the largest area (23.02 lakh ha) under sugarcane followed by Maharashtra (10.52 lakh ha), Karnataka (4.00 lakh ha) and Tamil Nadu (3.82 lakh ha) in terms of area. In India total production of sugarcane during 2014-15 was 244 lakh M.T. [5]. Over a decade, sugarcane production in India has been fluctuating between 233 and 355 M.T. and the average productivity at the farm level is as low as 40 t ha^{-1}. The production around the world is expected to reduce by 30% in the near future due to climatic changes [4]. The crop is facing a rough path ahead due to the increased input and labour cost. Lack of innovative technologies to boost the productivity is another constraint and there are fluctuations in sugarcane productivity. SSI offers practical solutions helping to increase the productivity of land, water, and work force. SSI also aims to reduce the crop duration, in turn may provide longer crushing period creating employment opportunities for extended duration. With this background information, the present investigation was undertaken to study the effect of growth, yield and water productivity of sugarcane cultivation in relation to methods of cultivation.

Materials and Methods
Field demonstrations were conducted at Western agro climatic zone of Tamil Nadu during 2012 to 2014 in main and ratoon crops of sugarcane following SSI and Conventional methods with an objective to increase the yield and productivity. Ten demonstrations in Bannari Amman sugar factory zone were conducted over a period of two years each demonstration was conducted in large sized plots (0.4 ha). The components of SSI *viz.,* planting of single seedling at wider spacing (5'x2') with drip fertigation were demonstrated in comparison with setts planted under drip irrigation. The soil of the experimental field was alkaline in nature with a P^H range of 6.5 to 8.34, bulk density 1.23 to 1.27 g cm^{-3} and electrical conductivity 0.28 to 0.31 dSm^{-1}, respectively. The soil texture was clay with 10.75 % coarse sand, 33.75 % silt and 55 % clay with medium depth. The moisture content at field capacity, permanent wilting point and available soil moisture were 41.28, 20.27 and 21.01 %, respectively.
The drip irrigation system was installed to meet out crop water requirement and for fertigation

of water soluble fertilizers (Table 1). Deep ploughing with disc plough was followed by operating twice with nine Tyne cultivators across the last plough. Well decomposed FYM @ 12.5 t ha^{-1} was applied at last ploughing and operated with rotovator to obtain fine tilth. Drip laterals were placed at 6" deep into the soil at spacing of 6 feet. The drip system was operated for 4 - 8 h. based on soil type. Pre emergence application of atrazine was applied on 3 DAP @ 2.5 kg. All other production technologies were followed as per the TNAU crop production guide 2014 [3].

Table 1: Fertigation schedule for sugarcane (kg ha^{-1})

Days after planting	N	P	K
0-30	39.40	0.00	0.00
31-60	50.60	26.25	9.00
61-90	56.50	20.50	14.50
91-120	60.20	16.25	16.00
121-180	57.80	0.00	40.50
181-210	10.50	0.00	35.0
Total	**275**	**63**	**115**

Thirty days old single seedlings var.CO 86032 was planted at wider row spacing of 150 x 60 cm at a depth of 3-5 cm. The main crop was planted during Sep.2012. The first ratoon was allowed from the 2nd Fortnight of Nov. 2013 and harvested during Sep. 2014. The quantity of water (lit.day^{-1}) to be applied through drip irrigation was calculated by following the climatological approach [1] and scheduled in alternate days. In surface irrigation system, the schedule was based on the soil moisture condition (once in 7-10 days). Plant height at harvest stage, number of internodes $cane^{-1}$, number of millable cane $clump^{-1}$, individual cane weight (kg) and cane yield (kg) were recorded. Economics of cultivation was worked out based on the prevailed market price of sugarcane. Water productivity was worked out by yield /total water consumed in terms of kg ha^{-3}.

Results and Discussion

Growth characters

Among the demonstration trials, the trial conducted at Kondapanayakanpudur recorded higher cane plant height (342 cm) under SSI. However, this was found to be on par with the trials conducted at Sokampalayam and Vinnapalli (Table 2). Overall mean value, indicated approximately 12% increase in plant height under SSI method. In ratoon sugarcane crop also, SSI method registered higher plant height (293 cm) than conventional planting (248 cm). Growth of sugarcane in terms of plant height was mainly due to wider spacing, more aeration and mother shoot removal on 30-35 DAP. Continuous water and nutrient availability under SSI induced development of more side tillers and enhanced uniform plant growth. Similar results were also observed in ratoon crop. The results corroborated with the findings of [8], which used single bud nursery. Transplanting of Seedling in the main field with wider row spacing utilized the main field with abundant solar radiation which in turn enhanced tillering and growth.

Yield attributes

The internodal length under SSI system registered higher value (13.73cm) than conventional system (10.95 cm). Number of internodes per plant (26.50), cane girth (9.77 cm), single cane weight (1.81 kg) and number of millable canes per clump (15.12) were also found to be higher under SSI method due to continuous supply of nutrient and water, more aeration and easy field operations. In addition, the yield was much higher under SSI method (167 t ha^{-1}) compared to conventional method (138 t ha^{-1}) of at Pattanveerthi Ayyanpalayam trial (Table 2). Based on the overall mean values 134 t ha^{-1} was achieved under SSI method of planting, while it was 111 t ha^{-1} under CV. (20.17 % yield increase). In ratoon crop yield attributes *viz.*, internodal length (cm), number of internodes per plant (no.), cane girth (cm), single cane weight (kg) and millable canes $clump^{-1}$ recorded higher values (13.28 cm, 23.40, 8.76 cm, 1.46 kg and 15.02, respectively) (Table 5). Continuous supply of water, and inputs at critical stages of crop growth might have increased the vigour and productivity. Among the locations Annur recorded higher yield under SSI (148 t ha^{-1}), where as Sathyamangalam location recorded yield (121 t ha^{-1}). These results are in conformity with the findings of [7] and [2]. Based on the overall mean values of ratoon crop, SSI registered 131.0 t ha^{-1} as compared to 104.0 t ha^{-1} under conventional method. This could be possible mainly because of the method of planting, optimum plant population and gap filling under SSI method. The favourable influence on cane weight could be occurred due to the supply of required quantity of water and nutrients at right time and right place as indicated by [6].

Quality parameters

The overall mean values of brix (%), polarity (%) and purity (%) were higher under SSI method (18.07, 15.05 and 83.29, respectively) in the main crop (Table 3) due to continuous supply of water and nutrient throughout the growth stages of sugarcane and resulting in synchronized maturity of tillers to millable canes. In ratoon crop also the brix (%), polarity (%) and purity (%) were higher under SSI method (18.31, 15.12 and 82.58, respectively) (Table 6). This influence could also be reasoned out mainly due to continuous supply of water and nutrient at peak requirement stages resulting in uniform maturity of tillers to millable canes.

Commercial cane sugar and sugar yield

The overall mean values revealed that SSI registered higher commercial cane sugar recovery (%) and sugar yield (t ha^{-1}) (10.38 and 13.99, respectively) compared to CV method (9.0 and 10.44, respectively) (Table 3). SSI ratoon crop also recorded higher commercial cane sugar recovery (%) and sugar yield (t ha^{-1}) (10.38 and 13.59, respectively) (Table 6) due to synchronized maturity of tillers to millable canes and appreciable cane quality parameters.

Water productivity and economics

Total water consumption and water productivity were worked out for both the methods of planting. SSI method showed less water consumption (1787 mm) and more water productivity (7.61 kg/m^3) as compared to conventional system (1927 mm and 5.82 kg m^{-3}). Gross return, net return and B: C ratio analysis indicated an additional net return of Rs.40, 610 ha^{-1} under SSI resulting in a B:C ratio of 1.91. (Table 4). In ratoon crop the total water consumed was1787 mm (Table 7) (with effective rainfall, but water productivity was higher under SSI (7.31 kg m^{-3}). SSI methods also recorded more gross return, net return and B:C ratio (Rs.3,00,610; Rs.1,65,660 and 2.22,respectively) when compared to conventional method (Rs. 2,40,350; Rs.1,18,100 and 1.96, respectively). An additional amount of Rs.13, 100 was incurred under SSI method which in turn increased net returns up to Rs.47, 560. The results were in conformity with the statement of [9] also

showed that SSI is one of the best methods to improve cane productivity with reduced cost of cultivation.

The overall system productivity indicated that SSI could record 265 t ha^{-1} (main + ratoon) as against 215 t/ha under conventional system (Table 8). The economics of production system as a whole indicated that SSI had registered higher cost of cultivation as Rs.2.98, 400 ha^{-1}. However, due to increased yield and quality canes, more net return Rs 3, 15,410 ha^{-1} could be possible, while, conventional system could give only Rs 2, 27,240 Rs ha^{-1}.

Table 2: Growth, yield attributes at harvest and yield of sugarcane (main crop)

Location	Plant height (cm)		Inter node length (cm)		No. of inter node per plant (No.)		Girth (cm)		Single cane wt. (kg)		No of millable canes /clump^{-1} (no.)		Cane yield (t ha^{-1})	
	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV
Kanoorputhur	316	295	12.80	9.30	26.01	24.02	10.78	8.24	1.50	1.45	11.90	10.47	129	115
Sokampalayam	330	271	14.90	11.20	31.02	22.01	11.45	8.90	1.62	1.39	14.00	12.65	141	119
Vinnapalli	328	289	13.90	10.00	28.03	20.07	9.10	7.70	1.56	1.28	13.30	10.56	127	101
Kondapanayakanpdur	342	285	14.70	10.20	27.04	21.03	9.80	7.20	1.51	1.37	14.70	11.58	138	110
Coimbatore	320	274	12.80	10.10	25.03	19.04	9.90	8.70	1.48	1.36	16.10	10.50	128	103
kembanayakanpalayam	268	239	12.40	11.50	22.10	20.02	9.70	6.70	1.51	1.38	15.40	11.90	124	108
Pattaverthi Ayampalayam	298	274	15.40	12.80	29.20	24.00	10.40	8.90	1.66	1.48	17.50	14.00	167	138
kembanaikanpalayam	216	180	12.56	11.00	20.21	18.00	8.50	6.90	1.32	1.01	15.40	10.50	116	93
Annur	284	235	16.07	13.00	25.12	21.00	8.90	8.20	1.56	1.41	16.10	11.90	131	104
Sathyamangalam	296	278	11.78	10.40	31.03	23.00	9.20	8.50	1.63	1.44	16.80	14.00	158	122
Mean	299	262	13.73	10.95	26.50	21.20	9.77	8.00	1.81	1.47	15.12	11.81	134	111
SEd	6.71		0.45		0.99		0.22		0.04		0.43		2.56	
CD	14.38		0.97		2.13		0.46		0.10		0.92		5.50	

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method

Table 3: Quality characters and sugar yield of main crop

Location	Brix content (%)		Polarity (%)		Purity (%)		CCS (%)		Sugar yield (t ha^{-1})	
	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV
Kanoorputhur	18.30	17.60	15.10	13.66	89.62	86.71	10.73	9.91	13.84	11.40
Sokampalayam	18.58	17.48	15.36	13.77	82.67	78.78	10.55	9.21	14.87	10.96
Vinnapalli	17.24	17.43	15.14	13.77	87.82	79.00	10.73	9.23	13.63	9.32
Kondapanayakanpdur	17.80	16.43	14.88	13.07	83.60	79.55	10.28	8.79	14.19	9.70
Coimbatore	18.40	17.43	14.98	13.77	81.41	79.00	10.21	9.23	13.07	9.51
kembanayakanpalayam	17.92	17.28	14.85	13.62	82.87	78.82	10.22	9.12	12.67	9.85
Pattaverthi Ayampalayam	18.53	17.57	15.21	13.68	82.08	77.86	10.41	9.09	17.38	14.81
kembanaikanpalayam	17.76	17.36	13.84	12.86	77.93	74.08	9.20	8.30	10.67	7.72
Annur	17.84	17.32	14.65	13.58	82.12	78.41	10.03	9.06	13.14	9.42
Sathyamangalam	18.33	17.00	15.18	13.58	82.82	79.88	10.44	9.16	16.50	11.75
Mean	18.07	16.99	15.05	13.44	83.29	79.21	10.38	9.01	13.99	10.44
SEd	0.33		0.25		0.56		0.17		0.32	
CD	0.70		0.54		1.20		0.38		0.69	

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method; CCS=Commercial cane sugar

Table 4: Water productivity and economics of sugarcane production (main crop)

Location	Total water consumed including ER (mm)		Water productivity (kg m^{-3})		Gross return (Rs.ha^{-1})		Cost of Cultivation (Rs.ha^{-1})		Net return (Rs.ha^{-1})		B:C ratio	
	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV
Kanoorputhur	1750	1900	7.37	6.52	296700	273700	159500	157000	137200	116700	1.86	1.74
Sokampalayam	1800	1950	7.83	6.10	324300	282900	165500	159000	158800	123900	1.95	1.78
Vinnapalli	1820	1980	6.98	5.10	292100	241500	158500	150000	133600	91500	1.84	1.61
Kondapanayakanpdur	1780	1870	7.75	5.88	317400	261200	164000	154500	153400	106700	1.93	1.69
Coimbatore	1860	1950	6.88	5.28	294400	246100	159500	151000	134900	95100	1.85	1.63
kembanayakanpalayam	1680	1820	7.38	5.93	285200	257600	157000	161500	128200	96100	1.82	1.60
Pattaverthi Ayampalayam	1780	1960	9.43	7.04	386400	326600	179000	168500	207400	158100	2.16	1.94
kembanaikanpalayam	1740	1900	6.67	4.89	266800	223100	153000	146000	113800	77100	1.74	1.53
Annur	1840	1990	7.12	5.22	301300	248400	160500	151500	140800	96900	1.88	1.64
Sathyamangalam	1820	1950	8.68	6.26	363400	289800	174000	160500	189400	129300	2.08	1.81
Mean	1787	1927	7.61	5.82	312800	265090	163050	155950	149750	109140	1.91	1.70

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method

Table 5: Growth, yield attributes and yield of ratoon sugarcane (ratoon crop)

Location	Plant height (cm)		Inter node length (cm)		No. of inter node per plant (No)		Girth (cm)		Single cane wt. (kg)		No of Millable cane clump^{-1}		Cane yield (t ha^{-1})	
	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV
Kanoorputhur	302	276	11.90	10.40	21.25	19.14	7.97	6.24	1.43	1.23	13.30	10.10	120	92
Sokampalayam	336	289	14.00	10.00	21.92	21.43	8.22	5.59	1.48	1.25	13.50	10.40	125	93
Vinnapalli	321	275	12.80	10.20	22.14	19.90	8.47	5.27	1.42	1.16	12.70	10.80	124	98
Kondapanayakanpdur	335	278	14.00	11.00	23.14	19.90	8.55	6.08	1.51	1.19	15.40	12.60	136	112
Coimbatore	318	268	13.50	11.10	21.36	18.37	8.22	5.99	1.45	1.25	14.00	11.20	126	97
kembanayakanpalayam	331	287	13.20	11.00	23.70	22.96	9.96	7.61	1.48	1.26	15.80	11.20	130	105
Pattaverthi Ayampalayam	246	199	15.70	10.20	25.47	17.60	8.20	7.80	1.49	1.38	16.90	15.40	135	121
kembanaikanpalayam	227	189	11.90	10.00	21.36	18.37	8.96	6.32	1.30	1.23	14.20	11.20	118	91
Annur	291	235	13.30	10.20	27.36	20.37	9.96	9.23	1.52	1.27	16.20	12.60	148	116
Sathyamangalam	227	188	12.50	11.50	26.36	18.37	9.13	7.70	1.49	1.32	18.20	14.00	145	120
Mean	293	248	13.28	10.56	23.40	19.64	8.76	6.78	1.457	1.25	15.02	11.95	131	104
SEd	2.88		0.41		0.30		0.28		0.05		0.43		2.56	
CD	6.18		0.88		0.65		0.61		0.12		0.93		5.49	

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method

Table 6: Quality characters and sugar yield of ratoon (ratoon crop)

Location	Brix (%)		Polarity (%)		Purity (%)		CCS (%)		Sugar yield (t ha^{-1})	
	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV
Kanoorputhur	17.91	17.00	14.80	13.60	82.64	80.00	10.17	9.18	12.20	8.45
Sokampalayam	18.10	17.00	15.40	13.22	85.08	77.76	10.74	8.78	13.42	8.17
Vinnapalli	18.10	17.00	15.20	13.60	83.98	80.00	10.53	9.18	13.06	9.00
Kondapanayakanpdur	18.11	18.11	14.50	14.11	80.07	77.91	9.79	9.38	13.32	10.51
Coimbatore	18.30	17.10	14.90	13.20	81.42	77.19	10.16	8.73	12.80	8.47
kembanayakanpalayam	18.30	18.10	15.40	13.90	84.15	76.80	10.68	9.17	13.88	9.63
Pattaverthi Ayampalayam	18.60	17.70	15.70	14.65	84.41	82.77	10.91	10.07	14.72	12.18
kembanaikanpalayam	18.64	17.90	14.26	13.90	76.50	77.65	9.38	9.23	11.07	8.40
Annur	18.40	17.84	15.64	14.50	85.00	81.28	10.90	9.87	16.13	11.45
Sathyamangalam	18.66	17.89	15.40	14.25	82.53	79.65	10.57	9.60	15.33	11.52
Mean	18.31	17.56	15.12	13.89	82.58	79.10	10.38	9.32	13.59	9.78
SEd	0.12		0.18		0.80		0.17		1.56	
CD	0.27		0.38		1.73		0.36		3.34	

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method; CCS=Commercial cane sugar

Table 7: Water productivity and economics of ratoon sugarcane under two methods of planting (ratoon crop)

Location	Total water consumed including ER (mm)		Water Productivity (kg m^{-3})		Gross return (Rs.ha^{-1})		Cost of Cultivation (Rs.ha^{-1})		Net return (Rs.ha^{-1})		B:C ratio	
	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV	SSI	CV
Kanoorputhur	1750	1750	6.86	5.26	276000	211600	130000	116000	146000	95600	2.12	1.82
Sokampalayam	1800	1800	6.94	5.17	287500	213900	132500	116500	155000	97400	2.17	1.84
Vinnapalli	1820	1820	6.81	5.38	285200	225400	132000	119000	153200	106400	2.16	1.89
Kondapanayakanpdur	1780	1780	7.64	6.29	312800	257600	138000	126000	174800	131600	2.27	2.04
Coimbatore	1860	1860	6.77	5.22	289800	223100	133000	118500	156800	104600	2.18	1.88
kembanayakanpalayam	1680	1680	7.74	6.25	299000	241500	135000	122500	164000	119000	2.21	1.97
Pattaverthi Ayampalayam	1780	1780	7.58	6.80	310500	278300	137500	130500	173000	147800	2.26	2.13
kembanaikanpalayam	1740	1740	6.78	5.23	271400	209300	129000	115500	142400	93800	2.10	1.81
Annur	1840	1840	8.04	6.30	340400	266800	144000	128000	200400	138800	2.36	2.08
Sathyamangalam	1820	1820	7.96	6.59	333500	276000	142500	130000	191000	146000	2.34	2.12
Mean	1787	1787	7.31	5.85	300610	240350	135350	122250	165660	118100	2.22	1.96

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method

Table 8: Economics of sugarcane production

Method	Yield (Rs.ha^{-1})			Cost of cultivation (Rs)			Gross return (Rs)			Net return (Rs)		
	Main crop	Ratoon	Total	Main crop	Ratoon	Total	Main crop	Ratoon	Total	Main crop	Ratoon	Total
SSI	134	131	265	163050	135350	298400	312800	300610	613410	165660	149750	315410
CV	111	104	215	155950	122250	278200	265090	240350	505440	118100	109140	227240

*SSI- Sustainable Sugarcane Initiative; CV- Conventional method

Conclusion

The results indicated that higher plant height at harvest stage under SSI method (299 cm) compared to CV planting (262 cm). Other yield attributing characters *viz.*, number of inter nodes/plant, number of millable canes/clump, girth, individual cane weight (kg/cane) and cane yield were also higher under SSI method with increased gross income, net return and B: C ratio both in main crop and ratoon crop. It was further observed that the water consumption was less (1820 mm) and water productivity was more (7.61 kg m^{-3}) in SSI method compared to conventional planting (1927 mm and 5.82 kg m^{-3} water consumption and water productivity, respectively).

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