International Journal of Agriculture Innovations and Research
Volume 5, Issue 4, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received: 20/01/2017 | Accepted on: 27/01/2017 | Published: 04/02/2017

Sugarcane Yield and Soil Nutrient Dynamics as affected by Interspecific Competition and Wider Row Spacing

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Abstract **– An investigation was carried out to study the effect of agronomic manipulations in sugarcane based cropping systems under drip irrigation at KIAAR, Sameerwadi, Tal: Mudhol, Dist: Bagalkot, Karnataka during 2013-2014. The experiment consisted of three wider row spacings i.e. 1.2 m, 2.4 m (paired row) and 3.6 m (paired row) and three intercrops *i.e.* soybean, greenpea and onion. The number of millable canes and cane yield under different intercropping systems did not differ significantly. In case of row spacings, 1.2 m recorded significantly higher cane yield (111 t ha^{-1}). The soil nitrogen content differed significantly due to various intercropping systems at 150, 210 DAP and at harvest. The soil nitrogen levels were significantly higher in sugarcane intercropped with greenpea (210.46, 238.34 and 190.95 kg ha^{-1}) and soybean (192.34, 231.37 and 179.80 kg ha^{-1}) at 150, 210 DAP and at harvest. Soil potassium differed significantly due to different cropping systems at 150, 210 DAP and at harvest.**

Keywords **– Greenpea, Intercropping, Onion, Soybean, Sugarcane, Wider Row Spacing**

I. INTRODUCTION

Sugarcane (*Saccharum* spp. hybrid complex) is an important commercial crop as 78 per cent of world sugar is produced from sugarcane. India ranks second, after Brazil, in area and production of sugarcane. The area occupying in the country is 4.7 million ha with the production of 28.10 million tons respectively [1]. In India, Karnataka stands 3rd in cane production next to Uttar Pradesh and Maharashtra states and 2nd with respect to sugar recovery after Maharashtra. Karnataka contributes for 15 per cent of total sugar production and 10 per cent of India's sugarcane production during 2014-15. In Karnataka, sugarcane is cultivated in 4.4 lakh ha area with a productivity of 90 t ha^{-1} during 2015-16 season. The total cane crushed in the state during 2015-16 was 376.65 lakh tonnes. Compared to cane crushed during 2014-15 (450.92 lakh tonnes), 16.60 per cent crushing was reduced during 2015-16 in Karnataka [16]. While farmers feel that they are abandoning sugarcane cultivation due to increase in cost of cultivation and decrease in profits.

Hence to increase the productivity of sugarcane in Karnataka, various agronomic measures that reduce cost of cultivation and improve the cane productivity should be adapted. In Karnataka, most of the farmers have been already growing sugarcane in 1.2 m spacing. Wide row spaced planting helps to provide abundant sunlight for increasing cane yield, provides proper space for intercropping and intercultural operations and also proper adoption of mechanization thereby increasing the per unit profitability [8]. Growing sugarcane in wide paired rows (> 1.5 m) provides ample scope for intercropping of short duration crops. So the farmer can earn additional income before the harvest of sugarcane.

The sugarcane crop depletes a considerable amount of nutrients from soil, but soybean in intercropping pattern increases productivity per unit of land and enables the crops more effectively utilize nutrients and improve soil fertility and field ecological conditions [3]. An intercropping partly meets the N requirement of the companion crop due to the transfer of the symbiotically fixed N from the legume to the non-legume [5]. Nitrogen, phosphorus and potassium utilization efficiency in maize/mungbean intercropping was significantly higher than that of the monoculture system [2]. Keeping all these aspects in view, the present study with an objective of knowing the beneficial effects of intercropping soybean, greenpea and onion under different row spacings of sugarcane and its effect on soil nutrient dynamics would give a solution.

II. MATERIAL AND METHODS

The field experiment was conducted at K. J. Somaiya Institute of Applied Agricultural Research (KIAAR), Sameerwadi, (Taluk: Mudhol, Dist: Bagalkot, Karnataka) which is located at 16˚ 19' N latitude and 75˚ 69' E longitude and at an altitude of 541 m above mean sea level. KIAAR, Sameerwadi comes under northern dry zone of Karnataka (Zone no. 3). During 2013-14 season, the crop received 118.5 mm rainfall in germination and establishment stage (35 days). During tillering stage (40-120 DAP), the sugarcane received 195 mm rainfall. There was no rainfall during grand growth stage (120-270 DAP) of the crop. Around 510.9 mm of rainfall occurred during ripening and maturation stage (270- 545 DAP). The total rainfall of 824.4 mm occurred during the entire 18 months crop growth period. The soil of experimental site was medium deep black. The composite soil sample from 0 to 30 cm depth was collected from the experimental area before planting of sugarcane and analyzed for chemical properties. The details of experiment with regard to crop, variety, the treatments evaluated, the design adopted and plot size are provided in table (2). Initially the land was ploughed once with tractor drawn mould-board plough and later on worked twice with the cultivator. The stubbles and weeds were picked from the

experimental site. The land was then harrowed and smoothened to bring the seed bed to a fine tilth. The field was then laid out as described below under different row spacings. The 'V' shaped ridges and furrows were formed at spacing of 1.2 m, with a furrow depth of 25 cm. In the paired row system, a pair of 'V' shaped furrows and ridges were formed at 30 cm spacing between the rows, with a furrow depth of 25 cm and such pairs were spaced at 2.4 m and 3.6 m apart, giving a paired row spacing of 2.4 m-30 cm-2.4 m and 3.6 m-30 cm-3.6 m.

On the day of planting cane setts, full doses of phosphorus (75 kg ha^{-1}), potash (190 kg ha^{-1}), zinc sulphate (25 kg ha^{-1}) and ferrous sulphate (25 kg ha^{-1}) along with 10 per cent of the recommended nitrogen (25 kg ha^{-1}) were applied in the form of diammonium phosphate (DAP), muriate of potash (MOP) and urea respectively through fertigation. The sugarcane crop was top dressed with 50, 75 and 100 kg urea per hectare at 6^{th}, 10^{th} and 14^{th} weeks after planting respectively. The recommended dose of fertilizers were applied to the intercrops *viz.* soybean, greenpea, cucumber and watermelon at the time of sowing where as for onion, 50 per cent of the total nitrogen and full doses of phosphorus and potash were applied at sowing in furrows by mixing with the soil and remaining 50 per cent nitrogen was top dressed at 30 days after sowing (DAS). The details are furnished in table (3).

From nine months old sugarcane crop (cv. Co86032) raised for seed multiplication, the two budded setts were prepared carefully. The setts were planted (12/07/2013) in normal method at 1.2 m spacing and in paired row system in 2.4 m and 3.6 m spacing. The seed rate for 1.2 m and 2.4 m spacing was 41667 two eye budded setts per hectare. The seed rate for 3.6 m row spacing is 27778 two eye budded setts per hectare. The setts were pushed down to a depth of 5 cm into the soil. At 4-5 days after planting of sugarcane, the seeds of intercrops *i.e.* soybean, greenpea and onion were dibbled in normal method of planting in furrows. The details regarding date of planting, seed rate, *etc*. are furnished in table (3).

The intercrops in sugarcane *viz.*, soybean, greenpea and onion were sown in row proportion of 1:4 in 1.2 m row spacing of sugarcane, 2:7 in 2.4 m row spacing of sugarcane (paired rows) and 2:10 in 3.6 m row spacing of sugarcane (paired rows). Pre-emergence application of herbicide Atrazine at the rate of 2.5 kg per ha was carried out at 3 days after planting (DAP) of sugarcane. Later hand weeding was taken up at 150 DAP after the harvest of all the intercrops. Earthing up was carried out at 150 DAP with the help of power tiller.

Since soybean suppressed sugarcane emergence, gap filling was carried out in sugarcane intercropped with soybean plots. The three months old tissue cultured sugarcane settlings of variety Co86032 were gap filled after the harvest of soybean. The method of irrigation adopted for the experiment was drip irrigation. Before the planting of sugarcane setts, the plots were two times irrigated by flooding. Later, the plots were irrigated three days in a week by drip method. During each time of irrigation, the water was supplied four hours per day. The rate of discharge of water in drip lines was two liters per hour.

Soil samples were collected form 0-15 cm depth at 150, 210 DAP and at harvest of plant cane from the experimental sites. These samples were analyzed for available N, P_2O_5 and K_2O by following the procedures given in table (1).

Table 1: Methods of estimation of soil N, P and K

Nutrient in soil	Method
Nitrogen	Modified Kjeldahl's method [13]
Phosphorus	Olsen's method [7]
Potassium	Flame photometric method [14]

Table 2: Details of the field experiment

Sl. No.	Particulars	Details	
1	Season	Plant cane (Adsali) July 2013 to December 2014	
2	Farming situation	Drip irrigated	
3	Number of treatments	Plant cane- 12	
4	Replications	Three	
5	Plot size- Gross plot	7.2 m × 14.4 m	
6	Design	Randomized complete block design	
	Row spacing between sugarcane	**Net plot size in plant crop**	**Net plot size in ratoon crop**
	1.2 m	5.2 m × 7.2 m	5.2 m × 4.8 m
	2.4 m (Paired row)	5.2 m × 9.6 m	5.2 m × 7.2 m
	3.6 m (Paired row)	5.2 m × 7.2 m	5.2 m × 7.2 m

Ratio of sugarcane and intercrops in different cropping systems			
	Plant cane		
Ratio Spacing	**Sugarcane : Soybean**	**Sugarcane : Greenpea**	**Sugarcane : Onion**
1.2 m spacing	100 : 84	100 : 84	100 : 84
2.4 m spacing	100: 75	100: 75	100: 75
3.6 m spacing	67 : 79	67 : 79	67 : 79

International Journal of Agriculture Innovations and Research
Volume 5, Issue 4, ISSN (Online) 2319-1473

Table 3: Details of variety, row arrangement, date of sowing/harvesting, seed rate and fertilizer application to sugarcane and different intercrops

Sl. No.	Crops	Name of the variety/ hybrid	Row proportion of sugarcane and intercrops			Date of planting/ sowing	Date of harvesting	Row spacing for intercrops	Seed rate/ha	Fertilizers (kg/ha)		
			1.2 m	2.4 m (Paired row)	3.6 m (Paired row)					N	P_2O_5	K_2O
1	Sugarcane (Plant crop)	CO86032	-	-	-	12/07/2013	06/12/2014	-	8 t/ha (2 eye bud setts)	250	75	190
2	Soybean	JS9305	1:4	2:7	2:10	16/07/2013	22/10/2013	30 cm × 10 cm	62.5 kg	40	80	25
3	Greenpea	AP3	1:4	2:7	2:10	17/07/2013	26/08/2013	30 cm × 10 cm	30 kg	25	50	50
4	Onion	N53	1:4	2:7	2:10	17/07/2013	24/11/2013	30 cm × 10 cm	10 kg	125	50	125

III. Results and Discussion

Effect of wider row spacing and intercrops on cane yield, number of millable canes and single cane weight

In case of row spacings, 1.2 m recorded significantly higher cane yield (111 t ha^{-1}). The interaction between row spacings and intercrops was not significant. With regard to different row spacings, the sugarcane yield was significantly higher at 1.2 m spacing (111 t ha^{-1}) compared to 2.4 m (89 t ha^{-1}) and 3.6 m (69 t ha^{-1}) row spacings (Table 4). Cane yield is a function of yield attributing characters such as number of millable canes (NMC), single cane weight, internodal length and cane diameter at harvest. In this study, the NMC was significantly higher in sugarcane at 1.2 m spacing (134717 ha^{-1}) compared to 2.4 m (98676 ha^{-1}) and 3.6 m (81114 ha^{-1}) row spacings. This could be attributed to more efficient utilization of moisture, nutrients and solar energy with less inter and intra plant competition in sugarcane grown at 1.2 m spacing. The results are in agreement with [11] where plant geometry 1.2 m normal row spacing found superior in increasing number of internodes, cane length, number of millable canes and cane yield as compared to 90 cm, 1.5 m and 1.5 m-30 cm-1.5 m row spacing. These results confirm the findings of [10] and [17]. Moreover, in paired row spacing at 2.4 m and 3.6 m, the lesser space was available within the pairs *i.e*. 30 cm. This may be the reason for higher inter plant competition within the paired rows at grand growth stage of sugarcane for utilization of available resources compared to single row planting in 1.2 m spacing. Even though the single cane weight of sugarcane did not differ significantly at different row spacings, the yields were lower in paired row spacing compared to single row cane at 1.2 m. This may be due to the production of higher number of tillers in sugarcane at 1.2 m spacing.

The three intercrops (soybean, greenpea and onion) had almost different growth patterns and canopies. This being the situation, soybean was quite fast in growth as well as covering the ground cover much early, thus inhibiting the emergence of sugarcane and further restricting the growth compared to other two intercrops. Due to this, large number of gaps was noticed and was filled by transplanting 90 days old sugarcane settlings after the harvest of soybean. By the end of the crop growth, these settlings had made their growth as compared to the cane grown with other two intercrops (greenpea and onion) thus producing similar yields in all the treatments. Probably had there been lesser number of rows of soybean, the impact on the growth of sugarcane would not have been as severe as noticed in the present experiment. Another reason due to which sugarcane in soybean could compensate its growth was because of 400 days which it got for the growth (Totally 545 days was the growth period).

With reference to different intercropping systems, there was no significant difference between yields, NMC and single cane weight of sole sugarcane and sugarcane grown with different intercrops (soybean, greenpea and onion) and yields ranged from 85 t ha^{-1} to 96 t ha^{-1} respectively. (Table 4). So it can be concluded that the intercrops onion and greenpea did not affect the growth and yield of sugarcane. This might be possible due to non-exhaustive and dwarf nature of the intercrop (onion) and residual effect of the additional fertilizers as well as cultural practices and irrigation applied to intercrops grown with sugarcane [4]. The results are also in conformity with [12] where the intercropping of vegetable pea did not affect the cane yield adversely rather there was slight improvement over the pure cane.

But in case of cane + soybean intercropping, soybean suppressed the growth of sugarcane due to its high canopy coverage. This resulted in low emergence of sugarcane. But after the harvest of soybean at 110 DAP, the sugarcane plot was gap-filled with 90 days old settlings. In the present study, the plant cane was harvested at 18 months. So the transplanted settlings attained better growth and hence there was no significant difference between yield, NMC and single cane weight of sole sugarcane and sugarcane grown with soybean.

International Journal of Agriculture Innovations and Research
Volume 5, Issue 4, ISSN (Online) 2319-1473

Table 4: Sugarcane yield (t/ha), number of millable canes per ha and single cane weight (kg) at harvest as influenced by different row spacings and intercrops

Spacing / Intercrop	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
	Sugarcane yield (t/ha)				Number of millable canes/ha				Single cane weight at harvest (kg)			
Sugarcane + Soybean	109	89	56	**85**	127353	102526	68737	**99539**	1.00	1.00	0.92	**0.97**
Sugarcane + Greenpea	114	93	83	**96**	140688	94296	91145	**108710**	0.92	1.08	1.08	**1.03**
Sugarcane + Onion	110	82	74	**89**	140268	89699	81597	**103854**	0.92	1.00	1.00	**0.97**
Sole Sugarcane	111	94	64	**90**	130561	108185	82979	**107242**	1.00	0.92	1.08	**1.00**
Mean	**111**	**89**	**69**		**134717**	**98676**	**81114**		**0.96**	**1.00**	**1.02**	
	SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result	
Spacing	3.52	10.34	S		4178	12255	S		0.05	0.16	NS	
Intercrops			NS				NS				NS	
S X I			NS				NS				NS	

Effect of wider row spacing and intercropping systems on soil nutrient dynamics

The different row spacings did not have significant effect on the soil nitrogen content at 150, 210 DAP and at harvest. But the soil nitrogen content differed significantly due to various intercropping systems at 150, 210 DAP and at harvest. The soil nitrogen levels were significantly higher in sugarcane intercropped with greenpea (210.46, 238.34 and 190.95 kg ha-1) and soybean (192.34, 231.37 and 179.80 kg ha-1) at 150, 210 DAP and at harvest. The interaction between row spacings and intercrops was not significant (Table 5). Higher available nitrogen content in soils of cane grown with pulse intercrops justifies the greater availability of N in pulse intercrops compared with other intercrops. This may be due to the more soil microbes that are present, the more unavailable nitrogen can be converted into inorganic nitrogen compounds which will be absorbed by plants, accelerating nitrogen transformation, and improving nitrogen utilization. Unavailable nitrogen can be more converted into inorganic nitrogen as the urease activities increase. The decline in available nitrogen under sugarcane alone might be due to the lack of the additional dose of chemical N given for the intercrop and also the resultant biomass due to various intercrops [15]. The results are in line with [6]. The effect of different row spacings and intercrops was not significant on soil phosphorus levels of sugarcane at 150, 210 DAP and at harvest. The interaction between row spacings and intercrops on soil P2O5 content was also not significant (Table 6).

The effect of different row spacings was not significant on soil potassium levels of sugarcane at 150, 210 DAP and at harvest. However, soil potassium differed significantly due to different cropping systems at 150, 210 DAP and at harvest. The interaction between row spacings and intercrops was not significant except at 150 DAP. Soil potassium level was significantly higher in sugarcane + greenpea (568.80 kg ha-1) which was on par with sugarcane + soybean (552.53 kg ha-1) at 150 DAP. Significantly higher potassium level in soil was also noticed in sugarcane + greenpea (481.09 kg ha -1) at 210 DAP and it was on par with sugarcane + onion (477.92 kg ha-1) and sugarcane + soybean (467.18 kg ha-1). At harvest, soil potassium was significantly higher in sugarcane + onion (517.77 kg ha-1) which was on par with sugarcane + greenpea (504.57 kg ha-1) and sugarcane + soybean (489.18 kg ha-1). Higher levels of available soil potassium in sugarcane intercropping systems compared to sole sugarcane at 150, 210 DAP and at harvest may be attributed to higher soil enzymatic activity in pulse crops compared to cereals (Table 7). The results are in accordance with [6]. Additional dose of fertilizers added to intercrops might also be one of the reasons for higher available potassium in sugarcane + onion at harvest.

International Journal of Agriculture Innovations and Research
Volume 5, Issue 4, ISSN (Online) 2319-1473

Table 5: Soil nitrogen content (kg ha^{-1}) as influenced by different row spacings and intercrops at 150, 210 DAP and at harvest of sugarcane

Spacing / Intercrop	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
	Soil N (kg ha^{-1})											
	150 DAP				210 DAP				At harvest			
Sugarcane + Soybean	192.34	171.43	213.25	**192.34**	234.16	238.33	221.61	**231.37**	183.98	188.16	167.25	**179.80**
Sugarcane + Green pea	246.69	192.34	192.34	**210.46**	229.97	209.07	275.97	**238.34**	196.52	209.07	167.25	**190.95**
Sugarcane + Onion	168.95	167.25	179.80	**172.00**	204.89	204.89	221.61	**210.46**	142.17	163.07	167.25	**157.50**
Sole Sugarcane	175.62	171.44	158.89	**168.65**	225.79	196.52	221.61	**214.64**	150.53	158.89	154.71	**154.71**
Mean	**195.90**	**175.62**	**186.07**		**223.70**	**212.20**	**235.20**		**168.30**	**179.80**	**164.12**	
	SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result	
Spacing			NS				NS				NS	
Intercrops	8.65	25.37	S		7.55	22.15	S		5.51	16.16	S	
S X I			NS				NS				NS	

Table 6: Soil phosphorus (P_2O_5) content (kg ha^{-1}) as influenced by different row spacings and intercrops at 150, 210 DAP and at harvest of sugarcane

Spacing / Intercrop	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
	Soil phosphorus (P_2O_5) (kg ha^{-1})											
	150 DAP				210 DAP				At harvest			
Sugarcane + Soybean	12.31	16.93	13.17	**14.14**	16.59	17.61	19.84	**18.01**	41.72	39.84	38.82	**40.13**
Sugarcane + Green pea	16.93	14.88	15.05	**15.62**	15.39	18.98	15.39	**16.59**	36.25	38.30	35.06	**36.54**
Sugarcane + Onion	16.93	13.17	15.05	**15.05**	19.84	16.59	17.61	**18.01**	38.48	39.84	37.28	**38.53**
Sole Sugarcane	15.91	15.56	15.22	**15.56**	21.89	18.81	17.61	**19.44**	34.54	36.42	38.30	**36.42**
Mean	**15.52**	**15.14**	**14.62**		**18.43**	**18.00**	**17.61**		**37.75**	**38.60**	**37.36**	
	SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result	
Spacing			NS				NS				NS	
Intercrops			NS				NS				NS	
S X I			NS				NS				NS	

Table 7: Soil potassium (K_2O) content (kg ha^{-1}) as influenced by different row spacings and intercrops at 150, 210 DAP and at harvest of sugarcane

Spacing / Intercrop	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
	Soil potassium (K_2O) (kg ha^{-1})											
	150 DAP				210 DAP				At harvest			
Sugarcane + Soybean	462.78	675.14	519.68	**552.53**	429.28	465.02	507.22	**467.18**	421.19	524.69	521.65	**489.18**
Sugarcane + Greenpea	638.50	561.79	506.15	**568.81**	489.22	527.56	426.50	**481.09**	528.64	539.57	445.49	**504.57**
Sugarcane + Onion	512.07	523.20	461.00	**498.75**	475.68	509.38	448.71	**477.92**	528.64	520.48	504.19	**517.77**
Sole Sugarcane	485.63	403.20	542.08	**476.97**	407.23	418.78	362.88	**396.30**	396.75	459.47	342.04	**399.42**
Mean	**524.75**	**540.83**	**507.23**		**450.35**	**480.19**	**436.33**		**468.80**	**511.05**	**453.34**	
	SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result		SEm±	CD (p=0.05)	Result	
Spacing			NS				NS				NS	
Intercrops	22.75	66.71	S		21.71	63.68	S		20.92	61.36	S	
S X I	39.40	115.55	S				NS				NS	

It was concluded that intercropping of sugarcane with greenpea and onion at 1.2 m spacing holds promise in realizing higher cane productivity. In conclusion, intercropping of sugarcane with greenpea at 1.2 m, 2.4 m-30 cm-2.4 m and 3.6 m-30 cm-3.6 m row spacings was far more effective than monoculture sugarcane to produce higher sugarcane yield, increase the per cent of soil inorganic nitrogen and potassium content which was positively correlated with biological nitrogen fixation by root nodules of legumes and enzyme activity in intercropping system.

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