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Shilpa V Chogatapur
Ph.D. Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

HT Chandranath
Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

RB Khandagave
Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Correspondence
Shilpa V Chogatapur
Ph.D. Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Economics and intercropping indices of sugarcane based intercropping system in ratoon cane

Shilpa V Chogatapur, HT Chandranath and RB Khandagave

Abstract
A field experiment was conducted at sugarcane research farm, Zadshyapur of S. Nijalingappa Sugar Institute (SNSI) of Belagavi which lies in northern transition zone of Karnataka (Zone-8) during 2017. The experiment was laid out in split plot design with four controls outside the experiment replicated thrice. The treatments included three row spacing as main plots (150 cm, 180 cm and 210 cm), inter cropping with sugarbeet, sweet sorghum and sweet potato with 1:1 and 1:2 ratio as sub-plots with four control plots (sole sugarcane (90 cm), sole sugarbeet, sole sweet sorghum and sole sweet potato) outside the experiment. On the basis of results obtained from present investigation, intercropping of sugarcane (150 cm) + sugarbeet 1:2 row proportion realised significantly higher net returns (₹ 2, 30, 211 ha $^{-1}$).Sugarcane (180 cm) + sweet sorghum 1:2 row proportion recorded significantly higher B:C (3.12) and found at par with sugarcane (150 cm) + sweet sorghum 1:2 row (3.12). Sugarcane (150 cm) + sweet potato with 1:2 row proportion recorded significantly higher LER (1.46). Sugarcane (150 cm) + Sugarbeet with 1:2 row proportion recorded significantly higher ATER (1.17). Significantly higher competition ratio (4.66) in sugarcane was recorded by sugarcane (210 cm) + sugarbeet with 1:1 row proportion.

Keywords: Sugarbeet, sweet sorghum, sweet potato, gross returns and net returns

Introduction
Sugarcane (*Saccharum officinarum* L.) is an important agro-industrial crop of tropical and sub-tropical regions of world and is cultivated in more than 110 countries. It is grown occupies in 26.09 million hectare with a production of 1, 842 million tonnes of cane (Anon., 2016) [2]. Sugarcane occupies an important position in Indian agriculture and plays a pivotal role in national economy by sustaining the second largest organized agro industry in the country next to textile.

In India it is grown in an area of 4.92 million hectares with a production of 348 million tonnes and average productivity of 70.72 t ha^{-1} (Anon., 2017) [1]. Among major sugarcane growing states in India, Karnataka occupies third position in area (0.45 million hectares), third rank in production (3.78 million tonnes) and fifth position in productivity (84.07 t ha $^{-1}$) (Anon., 2017) [1] in recent years sugarcane farming is facing serious challenges in terms of sustainability and is severely affected by multiple factors like climate change, escalating cost of production, labour scarcity, slashing sugar prices in the market, declining soil health *etc*. There is a little scope for increasing area under sugarcane due to heavy competition for food, fiber, oilseed, pulses *etc.* Therefore, the only alternative left is to increase the vertical production of sugarcane and sugar by finding out the efficient agronomic management practices. In recent years wider row planting technique (5 to 8 feet) is being popularized in tropical regions of sugarcane growing areas in India (Anon, 2013) [3]. Planting cane in wider rows helps in mechanization of several field operations *viz*., inter cultivation, aftercare and harvesting, thereby not only increases the efficiency but also results in reducing the cost of production.

Much of the space between two rows of sugarcane remains unutilized for an initial period of 100-120 days, because of its slow growth. Due to the wider row spacing and initial slow growth rate of sugarcane, there is ample scope for intercropping in sugarcane. Much of the space between two rows of sugarcane remains unutilized for an initial period of 100-120 days, because of its slow growth. Due to the wider row spacing and initial slow growth rate of sugarcane, there is ample scope for intercropping in sugarcane. The major objectives of intercropping are to produce an additional crop, to optimize the use of natural resources and to stabilize the yield of crops (Willey and Ruberts 1979) [7]. The space available in between the wide row can be suitably used for growing component crops for increasing the total production per unit area.

Keeping above facts in view, an investigation was carried out to study the effect of component crops in sugarcane with different row proportion for intensification of production in sugarcane based cropping system

Materials and Methods

The field experiment was conducted at sugarcane research farm, Zadshyapur of S. Nijalingappa Sugar Institute (SNSI) of Belagavi which lies in northern transition zone of Karnataka (Zone-8) during 2017. The soil of experimental field was low in organic carbon (0.41%) and available nitrogen (271.2 kg ha^{-1}) and medium in available phosphorus (29.10 kg ha^{-1}) and available potassium (241.32 kg ha^{-1}). The average rainfall of area was 970.8 mm but during 2017 a rainfall of 683.2 mm was received. The experiment was laid out in split plot design with four controls outside the experiment replicated thrice. The treatments included three row spacing as main plots (150 cm, 180 cm and 210 cm), inter cropping with sugarbeet, sweet sorghum and sweet potato with 1:1 and 1:2 ratio as sub-plots with four control plots (sole sugarcane (90 cm), sole sugarbeet, sole sweet sorghum and sole sweet potato) outside the experiment. The plant crop harvested on 25th January 2017 and allowed for ratooning.

Land equivalent ratio (LER)

It is defined as the relative land area under sole crops that is required to produce the yields obtained in intercropping at the same level of management. LER was worked out by using the following formula given by Willey (1979) [6].

LER= La + Lb = Ya/Sa + Yb/Sb

Where,

La and Lb = LER for the crop 'a' and 'b'

Ya and Yb = Individual crop yields under intercropping

Sa and Sb = Individual crop yields under sole cropping

Area time equivalent ratio (ATER)

The limitation in the use of LER is the emphasis on the land area without consideration of time the field is dedicated to production. To correct this deficiency, the LER was modified by Hiebsch and Maccollum (1980) [4] to include the duration of time the crop was on the land from planting to harvest. This method is known as the area time equivalent ratio (ATER). ATER was calculated by the formula evolved by Hiebsch and Maccollum (1980) [4].

$$ATER = \frac{(RYa \times ta) + (RYb \times tb)}{T}$$

Where,

RY = Relative yield of species 'a' and 'b'

$$RY = \frac{\text{Yield of intercrop per hectare}}{\text{Yield of monocrop per hectare}}$$

t = Duration (days) for species 'a' and 'b'

T = Total duration (days) of the intercropped system

Competition ratio (CRa)

The competition ratio of two crops is given by the ratio of their respective expected relative yields. Willey and Rao (1980) [8]

$$CR = \frac{LER_a}{LER_b} \times \frac{Z_{ba}}{Z_{bb}}$$

Aggressivity (A)

Aggressivity of crop A with crop B gives the simple difference between the expected relative yields only. If the aggressivity value of a component crop is zero, then the two component crops are said to be equally competitive. Aggressivity values of greater than zero indicate that one crop is dominating over the other. McGillchrist and Trenbath (1971) [5]

$$A_{ij} = \frac{\text{Intercrop yield of crop A}}{\text{Expected yield of crop A}} - \frac{\text{Intercrop yield of crop B}}{\text{Expected yield of crop B}}$$

$$A_{ij} = \frac{Y_{ij}}{Y_{ii} \times a_{ij}} - \frac{Y_{ji}}{Y_{jj} \times a_{ji}}$$

System productivity parameters were analysed for 21 treatments with 4 controls outside the experiment for analysing intercropping indices, Randomised Complete Block Desgin (RCBD) with 18 treatments was used. The mean values of main plot, sub-plot and interaction effects were separately subjected to Duncan's Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values under M–STAT - C program.

Results and Discussion

Data on gross returns (Rs ha^{-1}), net returns (Rs ha^{-1}), and B: C as influenced by different levels of row spacing, different component crops with varied row proportions and their interactions are presented in the Table 1. A row spacing of 150 cm recorded significantly higher gross returns (Rs 3,18,350 ha^{-1}) and followed by a row spacing of 180 cm (Rs 3,13,685 ha^{-1}) in plant cane. Among the component crops in sugarcane based intercropping system, sugarcane + sugarbeet 1:2 row proportion recorded significantly higher gross returns (Rs 3,19,065 ha^{-1}) and followed by sugarcane + sugarbeet 1:1 row proportion (Rs 3,14,478 ha^{-1}). The interaction effect of row spacings and component crops with different row proportion, sugarcane (150 cm) + sugarbeet 1:2 row proportion recorded significantly higher gross returns (Rs. 3,40,570 ha^{-1}) and followed by sugarcane (150 cm) + sugarbeet 1:2 row proportion ((Rs. 3,34,363 ha^{-1}). For comparing all the treatment combinations with four controls outside the experiment, all the treatment combinations recorded significantly higher gross returns over all the controls outside the experiment. A row spacing of 150 cm recorded significantly higher net returns (Rs 2,13,632 ha^{-1}) and found onpar with a row spacing of 150 cm (Rs 2,10,531 ha^{-1}). Among the component crops in sugarcane based intercropping system, sugarcane + sugarbeet 1:2 row proportion recorded significantly higher net returns (Rs 2,13,259 ha^{-1}) and found at par with sugarcane + sugarbeet 1:1 row proportion and sugarcane + sweet sorghum 1:2 row proportion The interaction effect of row spacings and component crops with different row proportion, sugarcane (150 cm) + sugarbeet 1:2 row proportion recorded significantly net returns (Rs. 2,30,211 ha^{-1}) and followed by sugarcane (150 cm) + sugarbeet 1:1 row proportion ((Rs. 2,25,235 ha^{-1}). For comparing all the treatment combinations with four controls outside the experiment, all the treatment

combinations recorded significantly higher net returns over all the controls outside the experiment.

A row spacing of 180 cm recorded significantly higher B: C (3.04) and found at par with a row spacing of 180 cm (3.04). Among the component crops in sugarcane based intercropping system, sugarcane + sweet sorghum 1:2 row proportion (3.11) and followed by sugarcane + sugarbeet 1:1 row proportion. The interaction effect of row spacings and component crops with different row proportion, sugarcane (150 cm) + sweet sorghum 1:2 row proportion recorded significantly higher B:C (3.12) and found at par with sugarcane (180 cm) + sweet sorghum 1:2 row. Lowest B:C was recorded by sugarcane (150 cm) + sweet potato 1:1 row proportion in plant cane. For comparing all the treatment combinations with four controls outside the experiment, all the treatment combinations recorded significantly higher B:C over all the controls outside the experiment.

The data computed on intercropping indices like Land equivalent ratio (LER), Area time equivalent ratio (ATER), Aggressivity and Competition ratio due to varied levels of row spacing, different component crops with varied row proportions and their interactions are presented in Table 2. Among treatments, sugarcane (150 cm) + sweet potato with 1:2 row proportion recorded significantly higher LER (1.46). Lower LER (1.09) was recorded by sugarcane 210 (cm) + sugarbeet with 1:1 row proportion. Sugarcane (150 cm) + sugarbeet with 1:2 row proportion recorded significantly higher ATER (1.17) and followed by sugarcane (180 cm) + sugarbeet with 1:2 row proportion (1.12). Lower ATER (0.95) was recorded by sugarcane (150 cm) + sweet potato with 1:1 row proportion. Among the treatments, significantly higher aggressivity (1.76) in sugarcane was recorded by sugarcane (210 cm) + sugarbeet with 1:1 row proportion. The lower agrresivity (0.55) was recorded by sugarcane (150 cm) + sweet potato 1:2 row proportion. Aggressivity of component crop significantly differed due to interactions of different levels of row spacing and different component crops with varied row proportions. Significantly higher aggressivity (-0.55) in component crop was recorded by sugarcane (150 cm) + sweet potato with 1:2 row proportion and followed by sugarcane (150 cm) + sweet potato with 1:1 row proportion. The lowest aggressivity (-1.64) in component crop was recorded by sugarcane (210 cm) + sugarbeet with 1:2 row proportion.

Competition ratio of sugarcane significantly differed due to interactions of different levels of row spacing and different component crops with varied row proportions. Significantly higher competition ratio (4.66) in sugarcane was recorded by sugarcane (210 cm) + sugarbeet with 1:1 row proportion and followed by sugarcane (180 cm) + sugarbeet with 1:1 row proportion. The lower competition ratio (0.77) in sugarcane was recorded by sugarcane (150 cm) + sweet potato with 1:2 row proportion. Significantly higher competition ratio (1.30) in component crop was recorded by sugarcane 150 + sweet potato with 1:2 row proportion and followed by sugarcane (150 cm) + sweet potato with 1:1 row proportion. The lower competition ratio (0.21) in component crop was recorded by sugarcane (210 cm) + sugarbeet with 1:1 row proportion.

Intercropping of sugarcane (150 cm) + sugarbeet 1:2 row proportion realised significantly higher net returns (₹ 2, 46, 829 ha $^{-1}$).Sugarcane (180 cm) + sweet sorghum 1:1 row proportion recorded significantly higher B:C (3.24) and found at par with sugarcane (180 cm) + sweet sorghum 1:2 row (3.24). sugarcane (150 cm) + sweet potato with 1:2 row proportion recorded significantly higher LER (1.47) and found at par with sugarcane (180 cm) + sweet potato with 1:2 row proportion (1.44). Sugarcane (150 cm) + Sugarbeet with 1:2 row proportion recorded significantly higher ATER (1.18).

Table 1: Economics of sugarcane system ratoon cane as influenced by different row spacings and intercrops

Treatment	Gross returns (` ha^{-1})				Net returns (` ha^{-1})				B:C			
Intercrops with row proportions (I)	Row spacing (S)											
	S_1 150 cm	S_2 180 cm	S_3 210 cm	Mean	S_1 150 cm	S_2 180 cm	S_3 210 cm	Mean	S_1 150 cm	S_2 180 cm	S_3 210 cm	Mean
I_1 : S.C + S.B 1:1	3,34,363^{b}	3,20,870^{de}	2,88,201^{gh}	3,14,478^{b}	2,25,235^{bc}	2,15,191^{de}	1,89,420^{hi}	2,09,949^{a-c}	3.06^{bc}	3.04^{c}	2.92^{f-i}	3.01^{c}
I_2 : S.C + S.B 1:2	3,40,570^{a}	3,24,963^{cd}	2,91,661^{g}	3,19,065^{a}	2,30,211^{a}	2,17,859^{c-e}	1,91,706^{gh}	2,13,259^{a}	3.09^{a-c}	3.03^{cd}	2.92^{f-i}	3.01^{c}
I_3 : S.C + S.S 1:1	3,25,347^{cd}	3,15,747^{e}	2,84,873^{h}	3,08,656^{c}	2,19,955^{b-d}	2,13,578^{e}	1,89,162^{hi}	2,07,565^{c}	3.09^{a-c}	3.09^{a-c}	2.98^{de}	3.05^{b}
I_4 : S.C + S.S 1:2	3,27,960^{c}	3,17,960^{e}	2,91,880^{g}	3,12,600^{b}	2,23,002^{bc}	2,16,158^{de}	1,96,763^{fg}	2,11,974^{ab}	3.12^{ab}	3.12^{ab}	3.07^{a-c}	3.11^{a}
I_5 : S.C + S.P 1:1	2,87,817^{gh}	2,98,537^{f}	2,74,210^{j}	2,86,854^{d}	1,88,417^{hi}	1,97,983^{f}	1,79,424^{j}	1,88,608^{d}	2.90^{hi}	2.97^{ef}	2.89^{i}	2.92^{d}
I_6 : S.C + S.P 1:2	2,83,490^{hi}	2,99,173^{f}	2,78,047^{ij}	2,86,903^{d}	1,84,746^{ij}	1,97,970^{f}	1,82,475^{j}	1,88,397^{d}	2.87^{i}	2.96^{e-g}	2.91^{g-i}	2.91^{d}
I_7 : Sole S.C	3,28,907^{bc}	3,18,547^{e}	2,87,112^{gh}	3,11,522^{bc}	2,23,857^{bc}	2,14,975^{de}	1,89,736^{hi}	2,09,523^{bc}	3.13^{a}	3.08^{a-c}	2.95^{e-h}	3.05^{b}
Mean of main plot	3,18,350^{a}	3,13,685^{b}	2,85,141^{c}		2,13,632^{a}	2,10,531^{a}	1,88,384^{b}		3.04^{a}	3.04^{a}	2.95^{b}	
Sole S.C (90 cm)	2,38373				1,32800				2.26			
Sole S.B	4,7250				14,274				1.43			
Sole S.S	4,1560				18,829				1.83			
Sole S.P	3,6270				13,209				1.57			
Mean with control	2,71347				1,78,677				2.81			
Sources	S.Em. ±		C.D. (p=0.05)		S.Em. ±		C.D. (p=0.05)		S.Em. ±		C.D. (p=0.05)	
Row spacing (S)	846		-		841		-		0.01		-	
Inter crop ratio (I)	1,135		-		1,132		-		0.01		-	
S × I	1,966		-		1,865		-		0.02		-	
Control	4,895		13,918		4,890		13,908		0.034		0.10	

S.C: Sugarcane S.B: Sugarbeet S.S: Sweet sorghum S.P: Sweet potato

Means followed by the same letter (s) within a column are not significantly differed by DMRT (p=0.05)

Table 2: Intercropping indices of sugarcane based intercropping system in ratoon cane

Treatments	LER	ATER	Competition ratio for sugarcane	Competition ratio for component crop	Aggressivity for sugarcane	Aggressivity for component crop
Sugarcane 150 cm + sugarbeet 1:1 row proportion	1.15^{hi}	1.07^{cd}	3.16^{c}	0.32^{gh}	1.67^{b}	-1.67^{i}
Sugarcane 150 cm + sugarbeet 1:2 row proportion	1.36^{c}	1.17^{a}	1.71^{j}	0.59^{d}	1.38^{e}	-1.38^{f}
Sugarcane 150 cm + sweet sorghum 1:1 row proportion	1.18^{fg}	1.02^{fg}	2.14^{g}	0.47^{e}	1.47^{d}	-1.47^{g}
Sugarcane 150 cm + sweet sorghum 1:2 row proportion	1.39^{b}	1.06^{de}	1.37^{m}	0.73^{c}	1.19^{g}	-1.19^{d}
Sugarcane 150 cm + sweet potato 1:1 row proportion	1.18^{fg}	0.95^{h}	1.23^{no}	0.81^{b}	1.00^{i}	-1.00^{b}
Sugarcane 150 cm + sweet potato 1:2 row proportion	1.46^{a}	1.01^{g}	0.77^{p}	1.30^{a}	0.55^{j}	-0.55^{a}
Sugarcane 180 cm + sugarbeet 1:1 row proportion	1.13^{i}	1.06^{de}	3.29^{b}	0.30^{h}	1.67^{b}	-1.67^{i}
Sugarcane 180 cm + sugarbeet 1:2 row proportion	1.26^{e}	1.12^{b}	2.27^{f}	0.44^{f}	1.53^{c}	-1.53^{h}
Sugarcane 180 cm + sweet sorghum 1:1 row proportion	1.16^{gh}	1.02^{fg}	2.47^{e}	0.40^{f}	1.54^{c}	-1.54^{h}
Sugarcane 180 cm + sweet sorghum 1:2 row proportion	1.36^{c}	1.06^{de}	1.50^{l}	0.67^{d}	1.26^{f}	-1.26^{e}
Sugarcane 180 cm + sweet potato 1:1 row proportion	1.19^{f}	1.00^{g}	1.60^{k}	0.62^{d}	1.25^{f}	-1.25^{e}
Sugarcane 180 cm + sweet potato 1:2 row proportion	1.37^{bc}	1.04^{ef}	1.19^{o}	0.84^{b}	1.02^{i}	-1.02^{b}
Sugarcane 210 cm + sugarbeet 1:1 row proportion	1.09^{j}	1.04^{ef}	4.66^{a}	0.21^{l}	1.76^{a}	-1.76^{h}
Sugarcane 210 cm + sugarbeet 1:2 row proportion	1.19^{f}	1.09^{c}	3.03^{d}	0.33^{gh}	1.64^{b}	-1.64^{j}
Sugarcane 210 cm + sweet sorghum 1:1 row proportion	1.13^{i}	1.01^{g}	3.05^{d}	0.33^{fg}	1.62^{b}	-1.62^{i}
Sugarcane 210 cm + sweet sorghum with 1:2 row proportion	1.32^{d}	1.06^{de}	1.77^{i}	0.57^{de}	1.38^{e}	-1.38^{f}
Sugarcane 210 cm + sweet potato 1:1 row proportion	1.15^{hi}	1.00^{g}	2.06^{h}	0.49^{e}	1.40^{e}	-1.40^{f}
Sugarcane 210 cm + sweet potato 1:2 row proportion	1.38^{bc}	1.06^{de}	1.28^{n}	0.78^{c}	1.11^{h}	-1.11^{c}
S.Em. ±	0.01	0.01	0.02	0.01	0.02	0.02

Means followed by the same letter (s) within a column are not significantly differed by DMRT (p=0.05)

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