Assessment of competitive indices in sugarcane-based intercropping systems under semi-arid region of Karnataka

SEEMANTINI NADIGER[1*] and CHANDRASHEKAR S HUNSHAL[2]

[1]**Sharad College of Agriculture, Jainapur, District Kolhapur 416101 Maharashtra, India**
[2]**University of Agricultural Sciences, Dharwad 580005 Karnataka, India**
[*]Email for correspondence: nadiger.seemantini@gmail.com

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ABSTRACT

Sugarcane productivity in the semi-arid regions of Karnataka is increasingly constrained by water scarcity, necessitating efficient cropping strategies to enhance resource use and farm income. A field experiment was conducted at KJ Somaiya Institute of Applied Agricultural Research, Sameerwadi, Karnataka, to evaluate the performance of sugarcane-based intercropping systems under different row spacings and to assess competitive interactions using various indices. The experiment comprised sugarcane planted at 1.2, 2.4 and 3.6 m spacings intercropped with soybean, green pea and drill sown onion. The results revealed that competition indices such as competition ratio (CR) and aggressivity (A) varied significantly among intercrops, with soybean exhibiting higher competitiveness against sugarcane, particularly during early growth stages. Land equivalent ratio (LER) values greater than unity in all intercropping systems indicated superior land use efficiency over sole cropping, with the highest LER (2.10) recorded in sugarcane + green pea at 3.6 m spacing. However, area time equivalent ratio (ATER) values were comparatively lower, suggesting overestimation by LER due to differences in crop duration. Drill sown onion emerged as the most productive and economically viable intercrop, recording the highest sugarcane equivalent yield (204 tonnes/ha) and relative production efficiency (156.25%). Although intercrop yields were lower than sole crops due to competition, intercropping systems significantly improved overall productivity and resource use efficiency. The study highlights that sugarcane planted at wider spacings with suitable intercrops, particularly onion, can enhance system productivity and profitability in water-limited environments.

Keywords: Sugarcane; Intercropping; Drill-sown onion; Green pea; Soybean; Wide row spacing; Semi-arid region; Resource use efficiency; Land equivalent ratio; Sugarcane equivalent yield

INTRODUCTION

Sugar output in the country has reached 225.30 lakh metric tonnes according to the National Federation of Cooperative Sugar Factories Ltd (NFCSF). The top three sugar-producing states: Uttar Pradesh, Maharashtra and Karnataka, account for 87.48 per cent of the total sugar produced in the country. Maharashtra leads with sugar production of 89.80 lakh metric tonnes, Uttar Pradesh follows with 65.60 lakh metric tonnes, while Karnataka has produced 41.70 lakh metric tonnes (Anon 2026).

In northwest Karnataka, sugarcane cultivators face irrigation water shortage during summer months and hence lower yields. Due to this, the sugarcane cultivated area in northwest Karnataka is decreasing gradually. Adapting wide row planting will provide abundant sunlight and proper space for intercropping, intercultural operations and also mechanization thus increasing the profitability (Panghal 2010). Cultivating sugarcane in wide paired rows (>1.2 m) provides ample space for intercropping of short duration crops like onion, green pea and soybean. By this, farmers are benefitted with additional income before the harvest of sugarcane.

Competition indices can help research scientists in many ways. By compressing experimental results, indices can ease the presentation of experimental outcomes (Hunt 1982). Growth and yield components of intercropping systems are affected by several factors such as planting ratio, spatial arrangement, plant density, cultivar and competition between component crops (Caballero et al 1995, Dhima et al 2007, Rezaei-Chianeh et al 2011). Among different factors, competition is the chief factor which has significant impact on growth and yield of plants in intercropping (Caballero et al 1995). The assessment of competition, land use, production efficiency, productivity and profitability of intercropping can be performed using indices such as sugarcane equivalent yield (SEY), competition ratio (CR), aggressivity (A), relative production efficiency (RPE), relative yield loss (RYL), actual yield loss (AYL), land equivalent ratio (LER), cropping intensity (CI), cultivated land utilization index (CLUI), land use efficiency (LUE), area time equivalent ratio (ATER), land equivalent coefficient (LEC), harvest diversity index (HDI), simultaneous cropping index (SCI), income equivalent ratio (IER), intercropping advantage (IA), monetary advantage index (MAI) and relative economic efficiency (REE). Keeping these aspects in view, the present experiment was conducted to assess sugarcane productivity under wide row spacings, evaluate different intercrops in plant cane and assess the effect of competition between component crops.

MATERIAL and METHODS

The field experiment was carried out at KJ Somaiya Institute of Applied Agricultural Research (KIAAR), Sameerwadi, Bagalkot, Karnataka located at 16°38'56" N latitude and 75°02'53" E longitude at an elevation of 541 m amsl. KIAAR, Sameerwadi is located in northern dry zone of Karnataka (Zone 3). During plant season, the crop received 118.5 mm of rainfall during germination and establishment stages (35 days). The plant cane was cultivated as an Adsali crop which received 824.4 mm rainfall during the entire 18 months crop growth period. The experimental site consisted of medium deep black soil. The method of irrigation was drip. The experiment included 12 treatments replicated thrice laid in randomized block design. Gross plot size was 7.2 m × 14.4 m. The row spacings of sugarcane were 1.2, 2.4 (paired row) and 3.6 m (paired row) with a net plot size in plant crop of 5.2 m × 12 m, 5.2 m × 9.6 m and 5.2 m × 7.2 m respectively. The ratios of sugarcane and intercrops in 1.2, 2.4 and 3.6 m spacing were 100:84, 100.75 and 67.79 in case of sugarcane:soybean, sugarcane:green pea and sugarcane:drill sown onion respectively.

At 120 cm spacing, the 'V' shaped ridges and furrows were formed with 25 cm furrow depth. In the paired row system, a pair of ridges and furrows was shaped at 30 cm apart between the rows, with a furrow depth of 25 cm and such pairs were structured at 240 cm and 360 cm apart, forming a paired row spacing of 240 cm-30 cm-240 cm and 360 cm-30 cm-360 cm. All the agronomic operations in sugarcane and intercrops were carried out as per recommendations of University of Agricultural Sciences, Dharwad, Karnataka.

The experimental data were analyzed and interpreted by using the Fischer's method of analysis of variance technique as explained by Gomez and Gomez (1984). The details regarding competitive indices used for assessment of the sugarcane-based intercropping system are provided in Table 1.

RESULTS and DISCUSSION

Effect of intercropping systems on competitive functions of the component crops

Efficiency indices are used to compare different intercropping systems with reference to land use and yield advantages. A number of cropping systems accomplished in an area have to be assessed to choose their suitability and relative advantages (Devasenapathy 2008). Some of the methodologies of concern to the current study were productivity, competition assessment, production efficiency and land use efficiency. Competition plays a major role in influencing yield of intercropping systems (Li et al 2011). A and CR indices have been used to evaluate the interspecific competition within intercropping (Dhima et al 2007). On the other hand, in the current study, different results were observed with respect to A and CR.

Among different row spacings, CR and A in sugarcane were higher at 3.6 m spacing compared to 1.2 m and 2.4 m spacings (Table 2). It could be due to higher yield of sugarcane in intercropped plots at 3.6 m spacing compared to sole sugarcane at 3.6 m spacing. Concerning different intercropping systems, in all the row spacings, CR and A values in sugarcane were higher in sugarcane + green pea and sugarcane + drill sown onion compared to sugarcane + soybean. This shows that sugarcane was more dominant over green pea and drill sown onion compared to soybean at different row spacings. In contrast to this, among different intercrops, CR and A values were higher in soybean compared to green pea and drill sown onion. This indicates that soybean was more competitive and dominant than sugarcane at different row spacings.

Table 1. Efficiency indices of intercropping systems

System	Index	Reference
Indices for productivity assessment in cropping system	Sugarcane equivalent yield (SEY)	Lal and Ray (1976)
Indices for competition assessment between intercrops	Competition ratio (CR)	Willey and Rao (1980)
	Aggressivity (A)	McGillchrist and Trenbath (1971)
Indices for assessment of production efficiency in cropping system	Relative production efficiency (RPE)	Devasenapathy (2008)
	Relative yield loss (RYL)	Banik and Bagchi (1996)
	Actual yield loss (AYL)	Banik (1996)
Efficiency indices for assessment of land use	Land equivalent ratio (LER)	Willey and Osiru (1972)
	Multiple cropping index (MCI/CI):	Dalrymple (1971)
	Cultivated land utilization index (CLUI)	Chuang (1973)
	Land use efficiency (LUE)	Devasenapathy (2008)
	Area time equivalent ratio (ATER)	Hiebsch and McCollum (1987)
	Land equivalent coefficient (LEC)	Adetiloye et al (1983)
Indices to assess profitability of cropping systems	Harvest diversity index (HDI)	Strout (1975)
	Simultaneous cropping index (SCI)	Strout (1975)
	Income equivalent ratio (IER)	Devasenapathy (2008)
	Intercropping advantage (IA)	Banik et al (2000)
	Monetary advantage index (MAI)	Ghosh (2004)
	Relative economic efficiency (REE)	Pasha et al (2018)
	Return per rupee invested	Akhtar et al (2000)
	Benefit-cost ratio (B:C)	Nadiger (2011)

Hence, growth parameters of sugarcane were severely affected by soybean during initial stages of crop growth.

Among different intercropping systems and row spacings, sugarcane at 3.6 m + green pea system recorded the highest RYL (29.69) and AYL (0.30) (Table 2). The AYL index provides more accurate information as compared to other indices on the inter and intra-specific competition of the component crops and the behaviour of each species in intercropping system (Banik et al 2000). Partial LER provides facts only on quantification of yield loss or gain due to interaction with other species or variation in plant population. Whereas, partial AYL illustrates the loss or gain in yield by its sign as well as its value. The LER values for all the intercropping treatments were greater than 1.00. This indicates that land use efficiency of sugarcane intercropping systems was higher than monocropping systems. In particular, the LER was the highest in sugarcane at 3.6 m + green pea (2.10). This indicates the most utilization of resources by this cropping system. Duration of the crops in field is not considered in LER. But it is dependent on the harvested products. However, the choice of mono-cropped yield for optimizing intercropped yield in the determination of LER is not clear (Willey 1979).

Area time equivalent ratio (ATER) offers a convincing comparison of the yield advantage of intercropping over monocropping in terms of disparity in time taken by the component crops (Aasim et al 2008). The data presented in Table 2 exhibit that ATER values were influenced by intercropping systems. In all the intercropping systems, ATER values were lesser than LER values indicating the over estimation of resource utilization due to the wide variations in the maturity periods of the crops of which sugarcane stayed longer on the land and had enough time to compensate for the intercrop competition.

ATER is free from complications of over estimation of resource utilization in contrast to LER.

Table 2. Efficiency indices in sugarcane-based intercropping systems as influenced by row spacings

T	Mix proportion (%)	SEY (tonnes/ ha)	Competition ratio		Aggressivity		RPE	RYL (%)	Actual yield loss		
			SC	IC	SC	IC			SC	IC	Total
T_1	100:84	136	0.92	1.09	–0.09	0.09	22.52	–1.80	–0.02	0.07	0.05
T_2	100:84	132	0.96	1.04	–0.04	0.04	18.92	2.70	0.03	0.07	0.10
T_3	100:84	204	1.13	0.88	0.12	–0.12	83.78	–0.90	–0.01	–0.13	–0.13
T_5	100:75	115	0.84	1.20	–0.19	0.19	21.81	–5.32	–0.05	0.13	0.08
T_6	100:75	107	1.06	0.94	0.06	–0.06	13.83	–1.06	–0.01	–0.07	–0.08
T_7	100:75	170	0.95	1.05	–0.04	0.04	80.85	–12.77	–0.13	–0.08	–0.21
T_9	67:79	82	1.21	0.82	0.23	–0.23	27.34	–12.50	–0.13	0.08	–0.05
T_{10}	67:79	99	1.91	0.52	0.92	–0.92	54.69	29.69	0.30	0.01	0.31
T_{11}	67:79	164	1.94	0.52	0.84	–0.84	156.25	15.63	0.16	–0.11	0.05

T: Treatment, T_1: Sugarcane at 1.2 m + soybean, T_2: Sugarcane at 1.2 m + green pea, T_3: Sugarcane at 1.2 m + drill sown onion, T_5: Sugarcane at 2.4 m + soybean, T_6: Sugarcane at 2.4 m + green pea, T_7: Sugarcane at 2.4 m + drill sown onion, T_9: Sugarcane at 3.6 m + soybean, T_{10}: Sugarcane at 3.6 m + green pea, T_{11}: Sugarcane at 3.6 m + drill sown onion; SEY: Sugarcane equivalent yield, SC: Sugarcane, IC: Intercrop, RPE: Relative production efficiency, RYL: Relative yield loss

Table 2. Contd…..

Planting pattern	Mix proportion (%)	LER	CI	CLUI	LUE	ATER	LEC
T_1: Sugarcane at 1.2 m + soybean (1:4)	100: 84	1.88	184	1.20	120	1.16	0.88
T_2: Sugarcane at 1.2 m + green pea (1:4)	100: 84	1.93	184	1.11	111	1.13	0.92
T_3: Sugarcane at 1.2 m + drill sown onion (1:4)	100: 84	1.73	184	1.22	122	1.15	0.73
T_4: Sole sugarcane at 1.2 m							
T_5: Sugarcane at 2.4 m + soybean (2:7)	100: 75	1.80	175	1.20	120	1.12	0.80
T_6: Sugarcane at 2.4 m + green pea (2:7)	100: 75	1.69	175	1.11	111	1.07	0.69
T_7: Sugarcane at 2.4 m + drill sown onion (2:7)	100: 75	1.56	175	1.22	122	1.02	0.60
T_8: Sole sugarcane at 2.4 m							
T_9: Sugarcane at 3.6 m + soybean (2:10)	67: 79	1.73	179	1.20	120	1.05	0.74
T_{10}: Sugarcane at 3.6 m + green pea (2:10)	67: 79	2.10	179	1.11	111	1.38	1.04
T_{11}: Sugarcane at 3.6 m + drill sown onion (2:10)	67: 79	1.86	179	1.22	122	1.31	0.81
T_{12}: Sole sugarcane at 3.6 m							

LER: Land equivalent ratio, CI: Cropping intensity, CLUI: Cultivated land utilization index, LUE: Land use efficiency, ATER: Area time equivalent ratio, LEC: Land equivalent coefficient

ATER values showed an advantage of 38 per cent in sugarcane at 3.6 m + green pea (1.38). This could be due to more efficient total resource exploitation and greater overall production than monocropping and the remaining intercropping arrangements. Similar to ATER, LEC was the highest in sugarcane at 3.6 m + green pea (1.04). The LEC emphasizes intercrop interactions and shows that intercropping systems with stable potentials are superior to their component crops cultivated as sole crops on per unit area productivity (Adetiloye et al 1983).

The concept of IER is related to LER with the exception of yield measurement in terms of net income instead of crop productivity. The IER for intercrops may differ from year to year since crop prices fluctuate. In the present study, higher values of LER were reported in sugarcane at 3.6 m + green pea (2.10) followed by sugarcane at 1.2 m + green pea (1.93). This could be because of higher yield of sugarcane when intercropped with green pea. The IA, which is an indicator of the economic feasibility of intercropping systems, affirmed that the most advantageous mixture was sugarcane at 3.6 m + green pea followed by sugarcane at 3.6 m + drill sown onion. As a consequence, a more satisfactory use of economic values would undoubtedly be to calculate the absolute value of the unpretentious yield advantage (Willey 1979).

Among different row spacings, CI was the highest in 1.2 m spacing (184%). As a consequence, higher cropping intensity indicates a higher percentage of the net area in which crops are cultivated more once during a single agricultural year. This also denotes higher yield per unit of agricultural land in an agricultural year. Regarding CLUI, the values were >1 in all the intercropping systems (Table 2), which indicates a better utilization of cultivated land by means of intercropping. Among different intercropping systems, sugarcane intercropped with drill sown onion at different spacings recorded the highest CLUI due to its longer duration compared to green pea and soybean. In the same way, LUE was higher in sugarcane + drill sown onion at different spacings. This shows the higher intensification of sugarcane intercropping with drill sown onion with the available resources in a given environment.

Many types of crops are included in intercropping systems. It is highly challenging to relate the pecuniary produce of one crop with another. The yield of sugarcane cannot be compared with yield of pulse crops and so on. In such situations, comparisons can be made based on economic returns (gross or net returns).

In the current research, yields of intercrops were converted into equivalent yield of sugarcane (SEY). SEY was the highest in sugarcane at 1.2 m + drill sown onion (204.00 tonnes/ha). This could be because of higher market value of drill sown onion as compared to prices of green pea and soybean during harvest of intercrops. Similar results were also reported by Mahadevaswamy and Martin (2002) where intercropping of drill sown onion increased SEY and LER in relation with sole cropping of sugarcane.

With regard to RPE, the values were positive in case of all the sugarcane intercropping systems (Table 2). This shows the superiority of these intercropping systems over the sole sugarcane in percentage and considered desirable. Sugarcane at 3.6 m + drill sown onion recorded the highest RPE (156.25), This can be attributed to higher yield and market value of onion in comparison to soybean and green pea.

The data in Table 3 indicate that intercrop yield was influenced by both the type of crop and the row spacing of sugarcane, with yields under intercropping generally lower than their respective sole cropping yields due to competition for light, nutrients and moisture. Soybean recorded yields of 18, 17 and 17 q per ha under 1.2, 2.4 and 3.6 m row spacings respectively, compared to 20 q per ha under sole

Table 3. Performance of intercrops as influenced by row spacings in sugarcane

Treatment	Intercrop yield (q/ha)
Soybean	
T_1: Sugarcane at 1.2 m + soybean (1:4)	18
T_5: Sugarcane at 2.4 m + soybean (2:7)	17
T_9: Sugarcane at 3.6 m + soybean (2:10)	17
T_{13}: Sole soybean	20
Green pea	
T_2: Sugarcane at 1.2 m + green pea (1:4)	9
T_6: Sugarcane at 2.4 m + green pea (2:7)	8
T_{10}: Sugarcane at 3.6 m + green pea (2:10)	7
T_{14}: Sole green pea	10
Drill sown onion	
T_3: Sugarcane at 1.2 m + drill sown onion (1:4)	47
T_7: Sugarcane at 2.4 m + drill sown onion (2:7)	44
T_{11}: Sugarcane at 3.6 m + drill sown onion (2:10)	45
T_{15}: Sole drill sown onion	64

cropping, showing only a slight reduction and suggesting that soybean is relatively compatible with sugarcane. In contrast, green pea exhibited a more pronounced decline, yielding 9, 8 and 7 q per ha across the same spacings as against 10 q per ha in sole cropping, indicating higher sensitivity to interspecific competition and possibly poorer utilization of the inter-row space at wider spacings. Drill sown onion performed comparatively better among the intercrops, producing 47, 44 and 45 q per ha under intercropping conditions at 1.2, 2.4 and 3.6 m row spacings respectively, although still lower than its sole crop yield of 64 q per ha; its relatively stable performance across spacings suggests better adaptability and efficient resource use. Across all intercrops, the 1.2 m row spacing tended to produce slightly higher yields, while increasing the spacing did not result in yield improvement, possibly due to suboptimal plant population and less efficient exploitation of available space. Overall, while intercropping reduced yields compared to sole cropping, onion emerged as the most suitable intercrop followed by soybean, whereas, green pea was the least compatible under the given conditions.

CONCLUSION

The present study demonstrates that sugarcane-based intercropping systems under wide row spacings offer a viable strategy to improve productivity and resource use efficiency in semi-arid regions. All intercropping systems recorded land equivalent ratio values greater than unity, confirming their advantage over monocropping in terms of land utilization. Among the intercrops evaluated, drill sown onion proved to be the most suitable due to its higher yield stability, economic returns and contribution to sugarcane equivalent yield. Soybean, although competitive in nature, exerted greater suppressive effects on sugarcane during initial growth stages, while green pea showed relatively lower compatibility under intercropping conditions.

Wider row spacing, particularly 3.6 m, enhanced competitive advantage and overall system efficiency, although intercrop yields tended to be slightly higher at 1.2 m spacing. The integration of suitable intercrops, especially onion, with sugarcane under optimized row spacing can, therefore, serve as an effective approach to enhance farm profitability, ensure better utilization of available resources and mitigate risks associated with water scarcity in the semi-arid regions of Karnataka.

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