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Magnitude of heterosis for yield and its components in sugarcane (*Saccharum officinarum* L.)

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Abstract
Studies on magnitude of heterosis in interspecific and intergeneric hybrids of sugarcane involving six lines (*Saccharum officinarum* cv. Badila (L_1) and five sugarcane varieties *i.e.*, CoC671 (L_2), CoC 85061 (L_3), CoC92061 (L_4), Co86032 (L_5), CoG93076 (L_6)) and three testers [*Saccharum wild* relatives, *Saccharum spontaneum* (T_1), *Erianthus arundinaceus* (T_2) and *Miscanthus sacchariflorus* (T_3) (latter two are related genera)] revealed pronounced hybrid vigour for cane yield and its attributes. Positive and significant relative heterosis and heterobeltiosis were recorded for number of millable cane per plot and cane yield per plot by $L_1 \times T_2$ and $L_5 \times T_2$. Also, $L_5 \times T_2$ recorded signiicant positive relative heterosis for internode length, cane thickness, number of millable cane per plot and cane yield per plot. Above said both hybrids were recorded positive significant standard heterosis for cane length, internode length, number of millable cane per plot and cane yield per plot. In general, L_1, L_5 and T_2 were found promisng parents. The present study suggested that exploitation of $L_1 \times T_2$ and $L_5 \times T_2$ should be more rewarding for future sugarcane breeding.

Keywords: Sugarcane, interspecific, intergeneric, relative heterosis, heterobeltiosis, Standard heterosis

Introduction
Sugarcane is an important commercial crop grown in the tropical and subtropical areas of the world. It is an important source of sugar and other sweeteners. Sugarcane belongs to the genus *Saccharum* and family Poaceae. Sugarcane is a complex polyploid derived through interspecific hybridization and back crosses involving three major species *viz.*, *Saccharum officinarum* L., *Saccharum barberi* and *Saccharum spontaneum.* Interspecific and intergeneric hybridization has provided the major break through in sugarcane breeding solving some of the disease problems but also providing additional and unexpectedly large increased yields, improved rationing ability and adaptability for growth under various stress condition (Rumke, 1934, Janakiammal, 1941, Price, 1967, Miller and Tai, 1992, Krishnamurthi, 1993, Amalraj, 2003, Anbanandan *et al.*, 2004, Rajeswari *et al.*, 2004).
The magnitude of heterosis provides a basis for determining genetic diversity and also serves as a guide to the choice of desirable parents (Loganathan *et al.*, 2001). The information on heterosis for cane yield, sugar yield and its attributes in interspecific and intergeneric progenies involving six lines and three testers in sugarcane is presented.

Materials and Methods
Six lines namely, *Saccharum officinarum* cv. Badila and sugaracne varieties (*Saccharum* species hybrid) *viz.*, CoC 671, CoC 85061, CoC 92061, Co 86032,
CoG 93076 were crossed with three testers which are *Saccharum* wild relatives: *Saccharum spontaneum, Erianthus arundinaceus* and *Miscanthus sacchariflorus*
(latter two are related genera) in an L × T mating design. Eighteen cross combinations along with their nine parents were grown in a randomized block design with four replications. Both parents and F_1s were raised each in a 5 m row with a spacing of 80 cm. Standard agronomic and plant protection measures were adopted. The biometrical observations on cane length, internode length, cane thickness, cane weight, brix per cent, sucrose per cent, purity coefficient, commercial cane sugar per cent, number of millable canes per plot, cane yield per plot and sugar yield per plot were recorded. Heterosis was estimated over the mid parent (MP), better parent (BP) and standard parent (SP) and tested for significance as suggested by Wynne *et al.* (1970).

Results and Discussion
The estimates of mean squares were highly significant for all the characters indicating considerable diversity of parents. *per se* performance revealed the superiority of *Saccharum*

officinarum cv. Badila (L_1) which recorded high mean values for three traits namely, cane thickness, cane weight, and cane yield per plot. The line Co 86032 (L_5) recorded high mean values for internode length and cane yield per plot (Table 1). Hence, *Saccharum officinarum* cv. Badila (L_1) and Co 86032 (L_5) could be rated as desirable parents for hybridization to improve cane and sugar yield. Among the testers, *Erianthus arndinaceus* (T_2) recorded high mean values for traits namely cane length, internode length, cane thickness, cane weight, and cane yield per plot. Hence, based on *per se* performance *Saccharum officinarum* cv. Badila (L_1), Co 86032 (L_5) and *Erianthus arundinaceus* (T_2) can be adjudged as superior parents.

The mean performance is the primary criterion to evaluate the merit of hybrid. Kadambavanasundaram (1980) and Nadarajan (1986) reported that *per se* performance of hybrids appeared to be a useful index for judging the hybrids. Based on *per se*, the hybrids *Saccharum officinarum* Badila × *Erianthus arundinaceus* ($L_1 \times T_2$) and Co 86032 × *Erianthus arundinaceus* ($L_5 \times T_2$) performed better based on the mean performance for traits cane yield per plot and its components. Most of the hybrids with tester *Erianthus arundinaceus* (T_2) exhibited higher mean performance for all the traits (Table 1), which stressed the importance of parental selection in hybridization programmes.

Information on the magnitude of heterosis is the pre-requisite in the development of hybrids. A good hybrid should manifest high amount of heterosis for commercial exploitation. High and low positive heterosis observed was mainly due to varying genetic composition between parents of different crosses for the components characters (Rajesh and Gulsan, 2001). Positive and significant relative heterosis and heterobeltiosis for number of millable cane and cane yield per plot were recorded by the hybrid *Saccharum officinarum* cv. Badila × *Erianthus arundinaceus* ($L_1 \times T_2$) which corroborate with the report of Rajeswari *et al.* (2004). The hybrid Co 86032 × *Erianthus arundinaceus* ($L_5 \times T_2$) recorded positive and significant relative heterosis for internode length, cane thickness, number of millable cane per plot and cane yield per plot and also it showed positive and significant heterobeltiosis for number of millable cane per plot (Table 2). The above both hybrids showed positive and significant standard heterosis for cane length, internode length, number of millable cane per plot and cane yield per plot. Positive and significant standard heterosis for cane yield and its contributing characters were reported by Tyagi and Lal (2007). Therefore, from the foregoing discussion, it may be concluded that the above two hybrids can be adjudges as best and can be exploited for hybrid vigour to increase the cane yield and sugar yield potential in sugarcane.

Table 1: Mean performance of parents and hybrids

Genotypes/ Hybrids	Cane length (cm)	Internode length (cm)	Cane thickness (cm)	Cane weight (kg)	No. of millable cane per plot	Cane yield per pot (kg)
L1	180.60	7.52	**3.50**	**2.50**	**28.90**	**72.42**
L2	200.25	8.08	3.10	1.60	35.80	56.42
L3	209.55	7.78	3.50	1.63	35.95	57.78
L4	189.90	7.55	2.88	1.47	39.60	58.33
L5	204.85	8.50	2.77	1.60	37.00	59.25
L6	174.75	7.10	3.00	1.47	35.15	52.78
T1	249.50	19.10	1.50	0.25	49.45	12.43
T2	290.15	23.18	2.12	0.43	42.40	18.70
T3	95.85	12.03	0.75	0.04	61.05	2.50
L1 X T1	193.92	12.35	2.50	0.87	38.30	32.97
L1 X T2	226.30	14.90	2.60	0.90	45.38	39.18
L1 X T3	115.28	11.03	1.75	0.53	33.07	17.00
L2 X T1	210.23	15.13	2.60	0.63	46.93	30.35
L2 X T2	244.00	15.06	2.60	0.50	50.45	25.83
L2 X T3	104.95	8.05	1.63	0.48	34.35	16.57
L3 X T1	228.90	9.92	2.65	0.58	44.65	26.05
L3 X T2	262.63	14.08	2.75	0.70	53.27	37.78
L3 X T3	113.95	9.75	1.87	0.60	32.45	18.78
L4 X T1	221.70	13.15	2.38	0.65	35.25	23.28
L4 X T2	241.98	15.50	2.50	0.80	41.50	33.15
L4 X T3	105.45	9.02	1.80	0.48	31.70	15.03
L5 X T1	222.28	14.30	2.52	0.58	44.52	26.15
L5 X T2	247.28	17.53	2.60	0.78	50.52	38.75
L5 X T3	107.70	9.33	1.63	0.65	37.05	23.82
L6 X T1	192.97	14.08	2.50	0.60	40.20	25.47
L6 X T2	225.75	17.35	2.57	0.67	45.70	31.30
L6 X T3	120.23	9.63	1.68	0.50	35.77	18.67
Commercial Mean	191.89 ± 5.29	12.28 ±0.05	2.38 ± 0.02	0.83 ± 0.02	40.98 ± 0.26	32.25 ± 0.74
SD	0.58	0.10	0.01	0.04	0.52	1.47

Table 2: Heterosis (%) of the progeny over mid parent, better parent and standard parent

Hybrids	Cane length (cm)			Internode length (cm)			Cane thickness (cm)			Cane weight (kg)			No. of millable cane per plot			Cane yield per plot (kg)		
	MP	BP	SP	MP	BP	SP	MP	BP	SP	MP	BP	SP	MP	BP	SP	MP	BP	SP
L1 X T1	-9.83**	-22.29**	-5.33**	-7.23**	-35.34**	45.29**	0.01**	-28.07**	-9.91**	-36.36**	-65.00**	-45.31**	-2.23**	-22.55**	3.51**	-22.27**	-54.47**	-44.35**
L1 X T2	-3.86**	-22.01**	10.47**	-2.93**	-35.71**	75.29**	-7.56**	-25.71**	-6.31**	-38.46**	-64.00**	-43.75**	27.28**	7.02**	22.64**	14.02**	-45.91**	3.88**
L1 X T3	-16.60**	36.17**	-43.73**	12.79**	-8.32**	29.71**	-17.65**	-50.00**	-36.94**	-58.06**	-79.00**	-67.19**	-26.46**	-45.82**	-10.61**	-54.62**	-76.53**	-71.31**
L2 X T1	-6.53**	-15.76**	2.62**	11.32**	-20.81**	77.94**	13.05**	-16.13**	-6.31**	-32.43**	-60.94**	-60.74**	10.09**	-5.11**	26.82**	-11.88**	-46.21**	-48.78**
L2 X T2	-0.49**	-15.91**	19.11**	-0.16**	-32.69**	83.53**	-0.48**	-16.13**	-6.31**	-50.62**	-68.75**	-68.75**	29.03**	18.99**	36.35**	0.11**	-54.23**	2.41**
L2 X T3	-29.11**	-47.59**	-48.77**	-19.90**	-33.06**	-5.29**	-15.58**	-47.58**	-41.44**	-42.07**	-70.31**	-70.31**	-29.07**	-43.73**	-7.16**	-43.74**	-70.62**	-72.03**
L3 X T1	-10.28**	-8.27**	11.74**	-26.14**	-48.04**	16.76**	6.00**	-24.29**	-4.50**	-38.67**	-64.62**	-64.06**	4.57**	-9.71**	20.68**	-25.85**	-54.95**	-56.08**
L3 X T2	5.11**	9.49**	28.20**	-9.05**	-39.27**	65.59**	-2.22**	-21.43**	-0.90	-31.71**	-52.94**	-56.25*	35.94**	25.65**	43.99**	0.21**	-34.62**	3.24**
L3 X T3	-25.38**	-45.62**	-44.37**	-1.52**	-18.92**	14.71**	-11.76**	-46.43**	-32.43**	-27.93**	-63.08**	-62.50**	-33.09**	-46.85**	-12.30**	-37.70**	-67.50**	-68.31**
L4 X T1	0.90**	-11.16**	18.23**	-1.31**	-31.15**	54.71**	8.57**	-17.39**	-14.49**	-24.64**	-55.93**	-59.38**	-20.83**	-28.72**	-4.73**	-34.20**	-60.09**	-60.72**
L4 X T2	0.81**	-16.60**	8.12**	0.90**	-33.12**	82.35	0.01**	-13.04**	-9.91**	-15.79**	-45.73**	-50.00**	1.22**	-2.12**	12.16**	-13.92**	-43.16**	-44.05**
L4 X T3	-26.19**	44.47**	-48.52	-7.79**	-24.95**	6.18**	-0.69**	-37.39**	-35.14**	-37.29**	-67.80**	-70.31**	37.01**	-48.08**	-14.32**	-50.60**	-74.24**	-74.64**
L5 X T1	-2.17**	-10.93**	8.51**	3.62**	-25.13**	68.24**	18.13**	-9.01**	-9.01**	-37.84**	-64.06**	-64.06**	3.01**	-9.96**	20.34**	-27.03**	-55.86**	-55.86**
L5 X T2	-0.09**	-14.78**	20.71**	10.66**	-24.38**	106.18**	6.12**	-6.31**	-6.31	-23.46**	-51.56**	-51.56**	27.27**	19.16**	36.55**	0.58**	-34.60**	3.60**
L5 X T3	-28.37**	-47.42**	-47.42**	-9.14**	-22.45**	9.71**	-7.80**	-41.44**	-41.44**	-20.73**	-59.38**	-59.38**	-24.43**	39.31**	0.14	-22.83**	-59.79**	-59.79**
L6 X T1	-9.04**	-22.67**	-5.80**	7.74**	-26.31**	65.59**	11.11**	-16.67**	-9.91**	-30.43**	-59.32**	-62.50**	-4.96**	-18.71**	8.64**	-21.86**	-51.83**	-57.00**
L6 X T2	-2.88**	-22.20**	10.20**	14.62**	-25.13**	104.12**	0.49**	-14.17**	-7.21**	-28.95**	-54.24**	-57.81**	17.86**	7.78**	23.51**	-12.42**	-40.69**	-47.17**
L6 X T3	-11.14**	-31.20**	-41.31**	0.65**	-19.96**	13.24**	-10.67**	-44.17**	-39.64**	-33.99**	-66.10**	-68.75**	-25.62**	-41.40**	-3.31**	-32.43**	-64.61**	-68.48**

*Significant at 5% level ; ** Significant at 1% level

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