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COMBINING ABILITY IN RELATION TO HETEROSIS FOR QUANTITATIVE CHARACTERS IN SUGARCANE

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ABSTRACT

Genetic variances were estimated by full-sib and half-sib analysis in sugarcane among the 30 F_1s involving 10 female lines and 3 testers. Variances due to lines were significant for stalk height, stalk girth, and stalk weight, whereas variance due to testers was significant only for stalk density. Variances due lines x testers were significant for stalk height and stalk girth. $\sigma^2A/\ \sigma^2D$ showed the predominant role of nonadditive gene action in the inheritance of No. of millable canes/stool, stalk height, stalk girth and stalk density, and additive gene action for stalk weight and stool weight. The degree of dominance was in the range of overdominance for No. of millable canes/stool, stalk height, stalk girth and stalk density. Lines contributed maximum to variances due to hybrids for all the characters except stalk density. On the basis of per se performance and gca effects, CoS 8210, Seo 271/78 and CoS 7931 were good general combiners for stool weight. On the basis of per se performance and sca effects and heterotic response, the crosses Sh 670/79 x Seo 4/79, P11598 x Seo 4/79, Seo 271/78 x CoS 7931 and UP1 x CoS 758 were best specific combinations for stool weight.

Key words: Line x tester analysis, combining ability, heterosis, sugarcane.

The study of the nature and magnitude of gene action governing various characters is essential for formulating efficient breeding programme for increasing productivity. The knowledge of combining ability together with per se performance of the parents and hybrids, and heterotic response helps the breeders in selecting suitable parents and crosses for their use in a systematic breeding programme. In view of the meagre information available on these aspects in sugarcane, the present investigation has been undertaken.

MATERIALS AND METHODS

Ten strains, namely, Seo 62/79, Seo 271/78, Sh 670/79, Sh 4/79, Sh 594/79, UP 1, P 11598, Seo 3/79, Cos 8210 and Co 1148, were crossed with each of the three male parents,

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i.e. CoS 7931, CoS 758 and Seo 4/79 in line x tester (L x T) design to obtain sufficient fluff of 30 F_1s in December, 1983 at the Genda Singh Sugarcane Breeding and Research Station, Seorahi, Deoria (U.P.). The fluff of all these F_1s were grown in nursery and single buds of the parents were planted in separate beds simultaneously in February, 1984. These 43 genotypes (13 parents + 30 hybrids) were transplanted together in randomized block design with three replications in March 1984. The distance between rows was 75 cm, between seedlings 50 cm, and the plot size was 5 x 2.25 m^2, with 30 seedlings transplanted in each plot. Normal agronomic practices were adopted during crop growth period. Observations were recorded on six quantitative traits, viz., number of millable canes/stool, stalk height, stalk girth, stalk weight, stalk density, and stool weight. Stalk density and volume were calculated by the following formula:

$$\text{Stalk density} = \frac{\text{Stalk weight}}{\text{Stalk volume}}$$

and

$$\text{Stalk volume} - \pi\,(d/2)^2 L$$

where d—stalk diameter and L—stalk length.

Analysis of variance, and general and specific combining ability (gca, sca) effects were estimated according to Kempthorne [1]. The average degree of dominance was calculated by using the formula of Kempthorne and Curnow [2]. Estimates of heterosis over mid- and better parents ((MP, BP) were obtained, and t–test was applied to test the significance using following formula:

$$t_{MP} = \bar{F}_1 - \overline{MP}/SE \text{ and } t_{BP} = \bar{F}_1 - \overline{B\,P}/SE$$

where SE of heterosis over MP = $\sqrt{\frac{3Me}{2r}}$ and SE of heterosis over BP = $\sqrt{\frac{2Me}{r}}$

RESULTS AND DISCUSSION

The analysis of variance showed highly significant differences among the genotypes for all the six characters. Variances due to parents were significant for all the characters except stalk height, indicating greater genetic diversity among the parents. Significant variances due to hybrids for all the characters, except number of millable canes/stool and stalk density, revealed high differences among the crosses. Variances due to parents vs hybrids were significant for all the characters except stalk height, indicating a substantial amount of heterosis for these traits.

ANOVA for combining ability for all the six characters studied is presented in Table 1. Variation due to lines showed significant differences for stalk height, stalk girth and stalk weight, whereas variation due testers was significant only for stalk density. The interaction between lines and testers were significant for stalk height and stalk girth.

Table 1. ANOVA for combining ability for six characters in sugarcane

Source	d.f.	Millable canes/stool	Stalk height	Stalk girth	Stalk weight	Stalk density	Stool weight
Lines	9	3.92	1741.3*	0.168**	111215.8**	0.018	3.03
Testers	2	0.37	532.9	0.044	18172.0	0.089*	2.26
Lines x testers	18	1.71	733.8*	0.043*	10634.5	0.027	0.67
Error	58	1.51	393.7	0.025	16452.1	0.026	1.28
σ^2gca (testers)		0.25	6.7	0.004	251.3	0.002	0.05
σ^2g (lines)		–0.05	111.8	0.014	11175.7	–0.001	0.96
σ^2g (pooled)		0.02	20.7	0.003	2772.3	0.001	0.10
σ^2s		0.07	113.4	0.006	–1939.2	0 .006	–0.21
σ^2A/ σ^2D		0.29	0.2	0.52	—	0.22	—
$(\sigma^2D/\ \sigma^2A)^{0.5}$		1.85	2.3	1.397	—	2.14	—
			Contribution to hybrids (%)				
Due to testers		1.11	3.6	3.7	3.0	21.69	10.32
Due to lines		52.89	52.3	63.7	81.5	19.23	62.27
Due to lines x testers		46.00	44.1	32.5	15.5	59.08	27.41

*P = 0.05, **P = 0.01.

The contribution of lines to the total sum of squares due to hybrids was higher than the testers and lines x tester interaction for all the characters except stalk density. The smaller contribution of line x tester interaction than either of lines or testers indicated high estimates of variances due to gca. While higher contribution of line x tester interaction for stalk density denotes the higher estimates of variances due to sca.

The ratio of σ^2A/ σ^2D (Table 2) for number of millable canes/stool, stalk height, stalk girth, and stalk density indicated the predominant role of nonadditive gene action (dominance or epistasis) in the inheritance of these traits. The degree of dominance $(\sigma^2D/\ \sigma^2A)^{0.5}$ was in the range of overdominance (>1). Yang et al. [3] and Miller [4] reported higher σ^2s than σ^2g for stalk number in half diallel and diallel analyses, respectively. Rao and Ethirajan [5] also found that nonadditive gene action played important role in the inheritance of stalk height.

The positive σ^2g estimates and negative σ^2s estimates for stalk weight and stool weight indicated the predominant role of additive gene action in the inheritance of these characters, which could be improved through simple selection by progeny testing or biparental progeny selection.

Table 2. Mean performance and gca effects of parents for six quantitative characters in sugarcane

Parent tester	Millable canes per stool		Stalk height		Stalk girth		Stalk weight		Stalk density		Stalk weight	
	mean	gca	mean	gca	mean	gca	mean	gca	mean	gca	mean	gca
Testers:												
CoS 7931	6.53	–0.12	194.8	4.82	2.18	0.037	615.0	9.16	0.84	–0.053	4.30	–0.13
CoS 758	9.50	0.11	175.5	–3.00	2.01	0.002	453.3	18.72	0.82	0.057*	4.35	0.31
Seo 4/79	7.53	0.01	167.9	–1.82	1.67	–0.039	381.7	–27.88	1.23	–0.003	2.87	–0.19
SE (gi)		0.22		3.69		0.028		23.41		0.029		0.21
SE (gi-gj)		0.32		5.12		0.041		33.12		0.041		0.29
Lines:												
Seo 62/79	9.87	–0.35	176.0	5.11	1.55	–0.015	335.0	38.16	0.99	0.038	3.34	0.03
Seo 271/78	4.40	0.46	103.9	20.55**	2.54	0.011	785.0	71.60	1.17	–0.020	3.45	0.83*
Sh 670/79	5.33	0.70	190.3	–7.38	2.42	–0.158**	1018.3	–165.84**	1.20	–0.076	5.43	–0.18
Sh 4/79	6.87	1.07**	186.7	–12.84	1.81	–0.084	626.7	–69.18	1.30	0.047	4.25	–0.28
Sh 594/79	11.47	–0.38	194.0	10.22	1.66	–0.015	525.0	–4.07	1.30	–0.058	6.20	–0.21
UP 1	8.03	–0.48	184.8	15.44**	2.06	0.009	622.7	46.16	1.00	–0.014	5.10	–0.07
P 11598	7.20	–0.35	179.0	–14.60*	1.85	0.216**	475.0	70.27	1.06	0.003	3.57	0.09
Seo 3/79	4.37	–0.96	143.6	4.55	2.05	0.247**	519.0	204.16**	1.10	0.023	2.38	1.11**
CoS 8210	11.67	–1.01	182.5	1.21	1.56	–0.049	405.0	–44.18	1.17	–0.003	4.80	0.84**
Co 1148	5.87	0.59	172.3	–22.25**	2.20	–0.161**	603.3	–147.07**	0.94	0.060	3.48	–0.48
SE (gi)		0.49		6.62		0.053		42.75		0.053		0.37
SE (gi-gj)		0.58		9.35		0.075		60.47		0.076		0.53

*P = 0.05, **P = 0.01.

The gca effects and per se performance of the parents are presented in Table 2. The parents that proved to be good general combiners on the basis of their desirable gca effects and per se performance for specific characters were Sh 4/79, Co 1148, and Sh 670/79 for number of millable canes/stool; UP 1, Sh 594/79 and CoS 7931 for stalk height; Seo 3/79 and CoS 7931 for stalk girth; Seo 3/79 and Seo 271/78 for stalk weight; Co 1148 and Sh 4/79 for stalk density; and CoS 8210 and CoS 758 for stool weight. Overall, cvs. CoS 7931, CoS 758, Seo 62/79, Seo 271/78, Sh 4/79, UP 1, Seo 3/79 and CoS 8210 were good general combiners and these may be used for hybridization for obtaining desirable segregates.

Mean performance, sca effects, and heterosis MP and BP of the promising crosses are presented in Table 3. The knowledge of sca effects for desirable characters is of utmost importance in sugarcane, where F_1 is vegetatively propagated and directly released as variety. Desirable sca alone is of no practical value unless the per se performance of the hybrids exceeds the MP and BP. Hence, the crosses were judged on the basis of their per se

Table 3. Best specific crosses and heterosis for six quantitative characters in sugarcane

Character	Cross	Mean	Sca	Heterosis (%)	
				MP	BP
Millable canes/stool	Sh 670/79 x Seo 4/79	8.47	1.57*	31.72**	12.48**
	Seo 271/78 x CoS 7931	7.53	1.02	37.75**	15.31**
	UP 1 x CoS 7931	5.90	0.32	18.95**	-26.53**
	P 11598 x CoS 758	6.53	0.73	-33.06	-41.79
	Sh 4/79 x CoS 758	7.80	0.45	-4.07	-17.89
SE			0.71	1.17	0.82
Stalk height	Sh 594/79 x CoS 7931	215.67	23.18	10.94	10.13
	Seo 62/79 x Seo 4/79	199.00	18.26	15.72	13.07
	CoS 8210 x CoS 758	195.67	20.00	9.33	7.23
	UP 1 x Seo 4/79	202.00	10.93	14.53	9.31
	Sh 670/79 x Seo 4/79	178.20	9.95	-0.52	-6.37
SE			11.46	17.20	12.17
Stalk girth	CoS 8210 x Seo 4/79	2.28	0.19	41.18	36.53
	Sh 594/79 x CoS 7931	2.36	0.16	22.92	8.26
	Seo 3/79 x CoS 7931	2.56	0.10	21.04	17.43
	Seo 271/78 x Seo 4/79	2.26	0.11	7.36	-11.02
	Sh 670/79 x CoS 7931	2.16	0.10	-6.09	-10.74
	Co 1148 x CoS 758	2.10	0.08	-4.10	-4.55
SE			0.09	0.14	0.10
Stalk weight	Seo 271/78 x Seo 4/79	830.33	94.43	42.43	5.77
	Sh 594/79 x CoS 7931	774.00	76.73	35.79	25.85
	Sh 4/79 x CoS 7931	689.67	57.51	-11.09	10.05
SE			74.05	96.27	68.27
Stalk density	Co 1148 x CoS 7931	1.27	0.20	42.06	34.53
	Seo 62/79 x CoS 758	1.24	0.09	36.57	25.05
	Sh 670/79 x CoS 758	1.14	0.10	11.87	-5.96
	Sh 594/79 x CoS 758	1.12	0.07	5.32	-14.06
SE			0.09	0.16	0.11
Stool weight	Sh 670/79 x Seo 4/79	4.50	0.80	8.43	17.13
	P 11598 x Seo 4/79	4.52	0.55	47.23	26.61
	Seo 271/78 x CoS 7931	5.24	0.46	35.22	21.86
	UP 1 x CoS 758	4.70	0.38	-0.53	-7.84
SE			0.65	0.88	0.62

Note: Heterosis over midparent (MP) and better parent (BP).

performance, sca effects and heterotic response for stool weight and its components. Some crosses had higher per se performance and sca effects but negligible negative heterosis over MP and BP. These were also considered as promising specific combiners. The crosses found to be the best on the basis of per se performance, sca effects and heterotic response were, Sh

670/79 xSeo 4/79, Seo 271/78 x CoS 7931, UP 1x CoS 7931 and Sh 4/79 x CoS 7931, Seo 62/79 x Seo 4/79, CoS 8210 x CoS 758, UP 1 x Seo 4/79, and Sh 670/79 x Seo 4/79 for stalk height; CoS 8210 x Seo 4/79, Sh 594/79 x CoS 7931, Seo 3/79 x CoS 7931, Seo 271/78 x Seo 4/79, Sh 670/79 x CoS 7931, and Co 1148 x CoS 758 for stalk girth; Seo 271/78 x Seo 4/79, Sh 594/79 x CoS 7931, and Sh 4/79 x CoS 7931 for stalk weight; Co 1148 x CoS 7931, Seo 62/79 xCoS 758, Sh 670/79 xCoS 758, and Sh 594/79 xCoS 758 for stalk density; and Sh 670/79 x Seo 4/79, P 11598 x Seo 4/79, Seo 271/78 x CoS 7931, and UP 1 x CoS 758 for stool weight.

A comparison of the sca effects of the crosses with gca effects of the parents involved in the best four crosses for stool weight revealed that all the crosses showing high sca effects had low x low combiners except Seo 271/78 x CoS 7931 which had high x high combiners. Chaudhary [6] also observed crosses with high sca effects due to low x low general combiners for some characters in barley which were attributed to dominance x dominance types of gene interactions. The cross Seo 271/78 x CoS 7931, having high sca effects and involving high x high combiners, indicated additive x additive type of gene interaction.

REFERENCES

1. O. Kepthrone. 1957. An Introduction to Genetical Statistics. John Wiley and Sons, Inc., London.

2. O. Kempthorne and R. N. Curnow. 1961. The partial diallel cross. Biometrics, **17**: 229–250.

3. T. C. Yang and C. C. Chu. 1962. Evaluation of combining ability in sugarcane. I. Report of Taiwan Sugar Exptl. St., **26**: 1–10.

4. J. D. Miller. 1977. Combining ability and yield component analysis in five parental diallel cross in sugarcane. Crop Sci., **17**(4): 545–547.

5. Nageshwar Rao and A. S. Ethirajan. 1983. Combining ability and evaluation of parents in 6 x 6 diallel cross of sugarcane (*Saccharum*). Maharashtra Sugar, **8**: 13–20.

6. B. D. Chaudhary. 1974. Estimation of Genetic Parameters in Barley by Diallel and Its Modifications. Ph. D. Thesis. Haryana Agricultural University, Hisar.