Estimates of general and specific combining ability for yield components in a partial sugarcane diallel cross

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ABSTRACT

The performance of 21 sugarcane progenies (*Saccharum* spp.) obtained in a diallel cross between three and seven varieties was evaluated from progeny tests conducted in Jaú Agronomy Experimental Station, Instituto Agronômico de Campinas, São Paulo State, Brazil. Measurements for average Brix, stool weight, stalk height, stalk diameter and stalk number were analyzed to obtain estimates of the relative magnitude of general (GCA) and specific combining ability (SCA) effects. Significant differences among GCA of the varieties were obtained for all characters, except stalk height, while significant differences among SCA effects were not expressed only for stalk height. An evaluation of variance components revealed that the variances of GCA for average Brix was almost the same of the component for SCA effects. A similar ratio for the two effects was obtained for stalk diameter. For average Brix, the ratio of GCA/SCA effects was bigger than the ratio observed for the other characters. This indicated that with the relatively bigger proportion of the genetic variance resulting from general effects, parental breeding value can be estimated from progeny of open-pollinated or polycross seed. The proportion of the genetic variance resulting from GCA effects of the other studied characters, the parental breeding value could be estimated from control-pollinated progeny tests.

KEY WORDS: *Saccharum* spp, variance components, sugarcane breeding.

INTRODUCTION

Most progeny testing programs for sugarcane (*Saccharum* spp.) are designed to obtain information about the breeding value of selected parents. A high breeding value is usually considered a high general combining ability (GCA) for the traits being tested.

Selection for high GCA assumes that each variety will cross-pollinate with a number of other varieties and that the majority of the seed production from the seed field will be from such crosses.

Interest in specific combining ability (SCA) is usually based on three considerations: 1) high specific combining ability is an indication of a relatively large amount of non additive variance affecting the trait under consideration; 2) the relative magnitude of SCA over GCA can be important to determine the method of progeny testing used for assessing breeding value; and 3) in some instances, high SCA can be used to establish seed fields which would use the dominant gene effects for the production of seeds having potential for great improvement in one trait.

GCA and SCA for agronomic characters in sugarcane have been studied for long time. Yang and Chu (1962) studied a composite diallel utilizing four varieties and discovered high values of GCA for stalk height and higher SCA than GCA for stalk number and stalk yield. Hogarth (1973) reported that the value of GCA was more significant consistent compared with SCA values for average Brix, stalk number, stool weight and stalk yield. Miller (1977) found significant differences for GCA for stalk weight, stalk number, stalk diameter, density, production of stalks, average Brix and sugar yield. Hogarth et al. (1981) reported that the additive genetic variance is important for some yield characters. They also reported the significance of non additive genetic variance for other characters such as average Brix and stalk number. These facts imply that the SCA is as important as the GCA. The GCA has been used more efficiently to recommend parentals for use in polycrosses and SCA for controlled pollination (Heinz and Tew, 1987).

Recently, Bastos (2001) showed the importance of the additive and non additive effects in the expression of five characteristics studied.

The data presented here are from a one-year progeny test of sugarcane in which seven varieties had been crossed as female parents with three male parents. Estimates of GCA and SCA are given for five yielding characteristics.

MATERIAL AND METHODS

Seven sugarcane varieties (SP84-2268, RB855453, RB835486, RB855113, SP77-5181, SP80-1842 e IAC87-3396) were used as female parents in crosses with each of three males (SP84-2268, RB855453 e RB835486) to make the 21 progenies used in this investigation. The progenies were grown at IAC Agronomy Experimental Station in Jau - SP, latitude 22º17'S, longitude 48º37W, altitude 580m. The soil is a well-drained dark red latosoil, dystrofic, clay texture, deep and with flat topography. The climate has a defined dry season, annual mean temperature of 21.6ºC, average humidity of around 70% with extremes of 77% in February and 59% in August.

The experiment was arranged in a randomized complete block design with three replicates. Each plot consisted of a single row with 30 plants spaced at 0.5m. Plot spacing was 1.5m. Data were taken six months after the first ratoon on each plot. For each data collection, all tillerings of each seedling stool were counted.

Yield component determination, like stool weight, stalk height, stalk number, stalk diameter, and average Brix were evaluated. For measuring stalk height, a ruler was used in five stalks. For measuring stalk diameter, a pachymeter was used in the same five stalks at a height defined as: height of the stalk divided by by three, measured from the base of the stalk. The average Brix was obtained by a reading of soluble solids from the sugarcane juice from each of the five stalks, being measured for "quantitative components" using a manual refractometer. Finally, for the determination of stool weight, all tillerings of each stool were cut and weighed on a scale.

The choice of the parental varieties was determined on the basis of their performance in the field.

Estimates of the GCA of a parental male variety was determined in relation to its performance in combination with all possible parental female varieties. The following linear model was assumed:

$$\mathbf{Y}_{ijk} = \mathbf{m} + \mathbf{g}_i + \mathbf{g}_j + \mathbf{s}_{ij} + \mathbf{e}_{ij}\boldsymbol{k} \quad \text{where,}$$

i: 1, 2 ... 3 and *j*: 1, 2 ... 7 and *k*: 1, 2, where Y_{ijk} denotes the value of the k^{th} experimental unit of the progeny of a cross of the i^{th} parental male variety and the j^{th} parental female variety. The term m is the common effect of the progenies in all replicates; g_i: common effect of the progenies of the i^{th} male variety; g_j: common effect of the progenies of the j^{th} female variety; s_{ij}: specific effect of the progeny of the cross of the i^{th} male and the j^{th} female varieties.

The sugarcane varieties used in this study were considered representative of the variability in maturity and plant morphology available among those used currently in the breeding program at the Instituto Agronômico de Campinas.

The analysis of variace among progenies is presented in Table 1. s^2_{gi} is an estimate of the genetic similarity of the parental male varieties and s^2_{gj} an estimate of the genetic similarity of the parental female varieties. The smaller the value of s^2_{gi} or s^2_{gj}, the higher would be the genetical proximity of the varieties. Similarly, σ^2_{Sij} is a measure of the importance of SCA effects, with a low value of σ^2_{Sij} indicating that the varieties performed as expected on the basis of their GCA.

RESULTS AND DISCUSSION

The analysis of variance for combining ability showed both GCA and SCA effects to be highly significant (p>0.01) for average Brix and stalk diameter (Table 2). For stool weight, the female GCA effects were

Table 1. Expected mean squares (EMS) of the analysis of variance used to analyze quantitative genetic traits in sugarcane progeny test in Jaú, São Paulo State, Brazil.

Source of Variation	d.f.	E.M.S.
$g_{i's}$ (g. c. a. of males)	2	$\sigma^2_e + r\sigma^2_s + mr\sigma^2_{gi}$
$g_{j's}$ (g. c. a. of females)	6	$\sigma^2_e + r\sigma^2_s + fr\sigma^2_{gj}$
$S_{i'j}$ (s. c. a.)	12	$\sigma^2_e + r\sigma^2_s$
Error	40	σ^2_e

significant ($p<0.05$) and the SCA effects were highly significant for average Brix, stool weight and stalk diameter, but not for stalk height.

Values of the ratio GCA and SCA were obtained for all characters in accordance with the model presented and are listed in Tables 3, 4, 5, 6 and 7. For each character, the means for each cross were transformed in percent of the mean of all crosses. In order to obtain the GCA effects for each variety and the SCA effects for each progeny, the computer program "Genes" (statistical package) was used, which was developed by the University of Viçosa, Brazil.

The largest ratio of GCA/SCA effect for average Brix (Table 3) was observed for the female parent RB855453 and for the male parent SP84-2268, indicating that these parents have good GCA and are expected to do well in most combinations. SP80–1842 and IAC87-3396 among the females and RB855433 and RB835486 among the male varieties exhibited the lowest GCA effects. Highest values for SCA effects were obtained with the SP80-1842 x SP84-2268 and IAC87-3396 x RB835486 crosses. Neither parent of the latter cross showed a high value for GCA, indicating that the expression of yield for this progeny was largely a result of SCA effects.

For stalk diameter (Table 4), only RB855453 and IAC87-3396 showed high GCA and no outstanding values for SCA effects were observed among the various progenies. SP80-1842 demonstrated the largest GCA effects for stalk number (Table 5) and SP84-2268, observed one of the highest values for SCA effects when crossed with RB835486. The highest values for GCA effects for stalk height among the female and male parents (Table 6) were exhibited by SP80-1842. The progeny of SP84-2268 with RB855453 showed the highest values for SCA effects for stalk height. For stool weight (Table 7), only SP80-1842 and RB835486 showed high GCA and RB855113 observed the highest values for SGA effects when crossed with RB855453.

Estimates of the variance components for GCA and SCA for all characteristics are given in Table 8. The

Table 2. Mean squares [1/] for general and specific combining ability for experiments established in Jaú, São Paulo State, Brazil, obtained from analysis of variance of five sugarcane yield components.

Variance Components	d.f.	Average Brix	Shoot Weight	Stalk number	Stalk diameter	Stalk Height
$g_{i's}$ (g. c. a. of males)	2	3.513**	14.6757**	12.6854**	0.1783**	0.0163 ns
$g_{j's}$ (g. c. a. of females)	6	21.9823**	2.5165*	2.0881ns	0.2030**	0.0736 ns
$s_{ij's}$ (s. c. a.)	12	9.3313**	14.6148**	8.7925*	0.0744**	0.0842 ns

[1/] *p>0.05; **p>0.01; [ns]: not significant.

Table 3. Estimates of general and specific combining ability effects for average Brix of single crosses of sugarcane in experiments established in Jaú, São Paulo State, Brazil.

Females	Males			General (g_i) effect of females
	SP84-2268	RB855453	RB835486	
	Specific effects (s_{ij})			
SP84-2268	-0.9781	0.5505	0.4277	0.0252
RB855453	-0.7448	0.2438	0.5010	1.3219
RB835486	-0.9715	0.7571	0.2145	1.1986
RB855113	-0.9648	1.0438	-0.0790	0.4219
SP77-5181	0.2619	0.3005	-0.5623	1.3552
SP80-1842	3.9352	-1.3562	-2.579	-2.3980
IAC87-3396	-0.5381	-1.5395	2.0777	-1.9247
General (g_j) effect of males	0.4648	-0.3138	-0.1509	

Table 4. Estimates general and specific combining ability effects for stalk diameter of single crosses of sugarcane in experiments established in Jaú, São Paulo State, Brazil.

Females	Males			General (g_i) effect of females
	SP84-2268	RB855453	RB835486	
Specific effects (s_{ij})				
SP84-2268	-0.0881	0.0576	0.0304	-0.1933
RB855453	0,0719	-0.2524	0.1804	-0.0733
RB835486	0.1086	-0.0057	-0.1029	-0.0900
RB855113	-0.0281	-0.0024	0.0304	-0.0233
SP77-5181	0.1519	-0.1224	-0.0296	-0.0133
SP80-1842	-0.2148	0.1809	0.0337	-0.2533
IAC87-3396	-0.0014	0.1443	-0.1429	0.1400
General (g_j) effect of males	-0.0919	0.0924	-0.0005	

Table 5. Estimates of general and specific combining ability effects for stalk number of single crosses of sugarcane in experiments established in Jaú, São Paulo State, Brazil.

Females	Males			General (g_i) effect of females
	SP84-2268	RB855453	RB835486	
Specific effects (s_{ij})				
SP84-2268	-2.4157	-0.0343	2.4501	0.1757
RB855453	0.7910	-1.8476	1.0567	-0.4809
RB835486	-1.7157	0.1557	1.5600	0.2657
RB855113	0.0377	1.1891	-1.2266	-0.1776
SP77-5181	1.5577	0.4309	1.1266	-0.4776
SP80-1842	0.8443	0.2257	-1.0712	0.8757
IAC87-3396	0.9010	0.7424	-1.6433	-0.1809
General (g_j) effect of males	-0.7209	-0.1024	0.8233	

Table 6. Estimates of general and specific combining ability effects for stalk height of single crosses of sugarcane in experiments established in Jaú, São Paulo State, Brazil.

Females	Males			General (g_i) effect Of females
	SP84-2268	RB855453	RB835486	
Specific effects (s_{ij})				
SP84-2268	-0.2828	0.2015	0.0815	-0.1129
RB855453	0.1705	-0.3152	0.1448	-0.0762
RB835486	0.0239	0.0082	0.0318	0.0005
RB855113	-0.0528	0.1215	-0.0685	0.0371
SP77-5181	0.1172	-0.0685	-0.0485	0.0271
SP80-1842	-0.0395	0.0248	0.0148	0.1638
IAC87-3396	0.0639	0.0282	-0.0918	-0.0395
General (g_j) effect Of males	-0.0271	-0.0014	0.0285	

Table 7. Estimates of general, and specific combining ability effects for stool weight of single crosses of sugarcane in experiments established in Jaú, São Paulo State, Brazil.

Females	Males			General (g_i) effect of females
	SP84-2268	RB855453	RB835486	
	Specific effects (s_{ij})			
SP84-2268	-3.1224	1.4962	1.6262	-0.7433
RB855453	1.2309	-3.4305	2.1995	-0.2666
RB835486	-1.4824	0.7562	0.7262	0.3867
RB855113	-0.7991	2.3695	-1.5705	0.3033
SP77-5181	2.0776	-0.8238	-1.2538	-0.2733
SP80-1842	0.0176	0.1162	-0.1338	0.8267
IAC87-3396	2.0776	-0.4838	-1.5938	0.2333
General (g_j) effect of males	-0.8476	0.0238	0.8238	

Table 8. Variance components for general and specific combining ability of sugarcane progenies in experiments established in Jaú, São Paulo State, Brazil.

Variance Components	Average Brix	Shoot Weight	Stalks Number	Stalks Diameter	Stalks height
$g_{i's}$ (g. c. a. of males)	1.4056	1.3442	0.9173	0.0143	0.0011
$g_{j's}$ (g. c. a. of females)	0.2757	0.0029	0.1115	0.0005	0.0024
$s_{ij's}$ (s. c. a.)	1.8883	4.5383	2.5859	0.0214	0.0099
Ratio GCA: SCA	0.3927	0.2968	0.3978	0.6916	0.3535

relative importance of additive and non additive genetic effects is indicated by the ratio of the GCA/SCA components. The variance components show a preponderance of specific effects, especially for stool weight, stalk diameter and stalk height. The specific effects values are of little use by themselves except to show the magnitude of effect variation. The data for average Brix indicate that the sum of the variance components for GCA effects was almost the same value of the components for SCA effects and the component for g_i effects was more than five times grater than the components for g_j effects.

For stalk diameter, the combined variance for GCA effects were markedly greater than the component for SCA effects. This progeny test indicated that, since the preponderance of genetic variation was due to SCA effects, the estimation of parental breeding value could not be accomplished by one of the more economical progeny testing methods, such as open-pollinated seed sugarcane germplasm bank on contol polycross seed. That is, if the SCA effect is high, a random male tester is not suitable if its effect is reasonably uniform.

The relatively lower ratio of the ratio GCA and SCA components for stool weight, stalk height and stalk number indicated that the higher proportion of genetic variance for this trait results from non additive gene effects. This also means there is more justification for establishing special seed sugarcane germplasm banks for the above characteristics than for average Brix and stalk diameter.

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RESUMO

Estimativas de Capacidade Geral e Específica de Combinação para Componentes de Produção de Cruzamentos em Dialelo em Cana-de-Açúcar

O desempenho de uma população de 21 progênies de cana-de-açúcar (*Saccharum* spp) obtidas por cruzamentos dialélicos de três por sete variedades foram avaliadas em um teste de progênie conduzido na Estação Experimental de Agronomia de Jaú, do Instituto Agronômico de Campinas, Estado de São Paulo, Brasil. Dados de Brix médio, peso de touceiras, altura de colmos, diâmetro de colmos e número de colmos foram analisados para obtenção das capacidades geral e específica de combinação. Diferenças significativas entre as capacidades geral de combinação (CGC) das variedades foram obtidas para todos os caracteres, exceto altura de colmos, enquanto diferenças significativas entre os efeitos da capacidade específica de combinação (CEC) só não foram significativas para altura de colmos. Uma avaliação dos componentes da variância mostraram que as variâncias para CGC para Brix médio foi quase o mesmo valor dos efeitos do componente para CEC. Valores semelhantes dos dois efeitos foram obtidos para diâmetro de colmo. Para Brix médio, os efeitos da relação CGC/CEC foram maiores do que a relação observada para alguns outros caracteres. Isso mostra que com a maior magnitude da variância genética resultante da CGC, o potencial do parental pode ser estimado das progênies resultantes de polinização aberta ou policruzamento. A menor magnitude da variância genética resultante da CGC dos outros caracteres estudados, mostra que o potencial dos parentais poderia ser estimado através de testes de progênies de polinização controlada.

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