Combining ability in eight selected clones of sugarcane (*Saccharum* sp)

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ABSTRACT

Eight commercial sugarcane (Saccharum sp) clones were crossed in a full diallel. Five characters were evaluated in the progeny in one or two harvests: Refractometer solids (Brix %), Yield (tons of cane per hectare, TCH), number of millable stalks, reaction to rust (*Puccinia melanocephala*) and pithiness. A sixth character, Brix yield (TBH) was calculated from TCH and Brix %. The eight parental clones were treated as fixed variables in the analysis. General combining ability (GCA) was significant for all 6 characters ($p<0.01$) and specific combining ability (SCA) was significant for Brix %, TCH, TBH and rust reaction in plant cane. The ratio between GCA and SCA was greater than 0.60, for all variables except for TBH in plant cane, indicating the predominance of GCA effects. The selection of high GCA parents for subsequent intercrossing in order to explore SCA is recommended, but some high value SCA combinations may be lost.

KEY WORDS: Diallel analysis, parental evaluation, sugarcane, general combining ability, specific combining ability.

INTRODUCTION

The choice of parents is a crucial step in a breeding program. In sugarcane the use of genetic parameters in parental evaluation is hindered by the high ploidy and complex chromosomal configuration of the species.

In the evaluation of combining abilities, genetic parameters that are not greatly affected by ploidy levels (Killick, 1977). Sprague and Tatum, 1942, proposed diallel crosses to estimate general combining ability (GCA) and specific combining ability (SCA). This method permits, when there is a predominance of GCA over SCA, parental evaluation based on the performance of F1 or more advanced progeny, indicating which group of genotypes associates, with greater frequency, favorable alleles for a given trait (Griffing, 1956; Miranda Filho and Geraldi, 1984). Additionally, diallel crosses provide information regarding genetic control of quantitative traits (Rumbaugh et al., 1988). Diploid inheritance and absence of linkage, epistasis and maternal inheritance are considered essential assumptions when estimating genetic parameters associated to quantitative traits (Cockerham, 1963). Nevertheless, Hogarth (1987), concludes that, although there is some imprecision, the genetic analysis of these traits is possible in sugarcane despite epistasis and polyploidy.

In sugarcane, Yang and Chu (1962), evaluated a complete diallel between four genotypes and found large GCA for stalk length and large SCA for number of stalks and cane yield. Miller, 1977, did not find any significant differences regarding the GCA for stalk weight, stalk number, stalk diameter, Brix % cane, cane yield and sugar yield, while SCA was significant for all traits. Diallel designs have also been applied to evaluate sugarcane genotypes with regard to disease and pest reaction such as mosaic resistance (Peixoto et al., 1988), nematodes (Dinardo-Miranda, 1990), rust (Ortiz et al., 1994) and smut (Balance et al., 1996).

The objective of this study was to estimate GCA and SCA of a group of sugarcane clones in order to identify superior parent clones and crosses within them.

MATERIAL AND METHODS

Eight sugarcane clones were crossed in all 28 possible combinations in May 1997, at the Copersucar crossing station at Camamu, Brazil. Clones RB845257, SP86-172, SP79-3314, SP80-1607, SP81-1763, SP81-3386, SP84-2029 and F154 were taken at random from a population of five hundred elite parents in the breeding program. To prevent selfing, all female inflorescences were emasculated using hot water treatment (Machado

Junior et al., 1996). Each progeny plot consisted of 70 seedlings planted in 5 rows (1.4 m apart) of 6 meters. Seedlings were planted 0.46 m apart in the row. The statistical design was a randomized complete blocks with four replications. The experiment was conducted for two harvests. Traits evaluated during the experiment are listed in Table 1.

Rust reaction was evaluated on the +1 leaf (first visible dewlap) on a 1 to 9 scale as described by (Purdy and Dean, 1981). Thirty plants from each plot were examined for pithness by splitting the stalk lengthwise and giving zero (no pith) to 3 (heavily pithed) grade as described by Nunes Junior et al. (1982).

Analysis of variance to determine the GCA and SCA for the traits in Table 1, followed the diallel design, model IV, proposed by Griffing, 1956, as follows:

$$Y_{ij} = m + g_i + g_j + s_{ij} + e_{ij}$$

where: m corresponds to the general mean; g_i e g_j refers to the general combining ability effects due to genotypes i and j, respectively; s_{ij} is the specific combining ability effect of the combination of genotypes i and j; and e_{ij} corresponds to the experimental error associated to plot ij.

The proportion of the variance explained by GCA in relation to SCA was estimated following Baker (1978), in which:

$$\frac{2Vgi}{2Vgi + Vsij}$$

where: Vgi corresponds to the variance due to the fixed effects of the general combining ability; and $Vsij$ is the variance due to the fixed effects of the specific combining ability, calculated as described by Cruz and Regazzi (1997).

RESULTS AND DISCUSSION

The mean squares of the joint (plant and ratoon) analysis of variance for the traits Brix %, TCH and TBH showed significant differences between plant and ratoon for Brix % ($p<0.01$) and TBH ($p<0.05$). The differences observed in TBH resulted from the differences in Brix %, since no significant differences between plant and ratoon was observed for the trait TCH. Significant differences ($p<0.01$) were observed for progenies for all three traits. Interactions between progenies and harvest (plant and ratoon) were not significant for Brix % but showed significance ($p<0.05$) for TCH and TBH. The average behavior of the progenies in plant and ratoon was therefore more consistent for Brix % than for yield (TCH).

As treatments x harvest interactions were not significant ($p<0.05$) for Brix %, the relative proportion of GCA to SCA was calculated. The value of 0.6250 indicated a predominance of an additive genetic variance similar to the conclusions presented by Wu et al., 1980 and Hogarth, 1980. Due to the interactions observed for TCH and TBH, the combining abilities for these traits must be analyzed separately for each harvest (Table 2).

General combining ability was significant ($p<0.01$) for TCH in plant and ratoon while specific combining ability showed significance only in plant cane. In spite of the considerable amount of dominant gene action, GCA was proportionally greater for TCH (0.7686 in

Table 1. Studied traits.

Character	Unit	Stage[1/]		Description
		Plant	Ratoon	
Brix %	Brix % juice	mai/98	ago/99	Juice sample from 8 plants
TCH	Tons cane per hectare	nov/98	set/99	Weight of stalks transformed to tons of cane per hectare (TCH)
TBH	Tons Brix % per hectare	nov/98	set/99	(Brix % x TCH)/100
#Stalk	Number of stalks		ago/99	Mean number of stalks per plant
Rust	Percent (%)	mar/98		Percent plants with rust grade greater than 4
Pith	grade		ago/99	Grade transformed by $\sqrt{(x+0.5)}$

[1/] Month/year of evaluation.

ratoon) and slightly less for Brix (0.625). This contrast with Hogarth, 1980, who found predominantly additive genetic variance for Brix % and non additive for yield and its components. The specific set of parental clones used may be responsible for these differences.

For sugar yield (TBH), which results from the product of cane yield (TCH) and cane quality (Brix %), the analysis showed similar results as the individual components.

Significant differences ($p<0.01$) were observed with regard to rust reaction, stalk number and pithiness; however, for stalk number, the GCA was significant and the SCA non-significant. These results are similar to those obtained by Wu et al. (1980) and contrary to the findings of Miller (1977), and Yang and Chu (1962). The larger proportion of GCA in these traits (71.23 % to 85.37%) indicates greater additive genetic effects, although for rust, the dominant gene action was also found to be significant.

Estimates for GCA for Brix % (mean plant and ratoon) and for one stage only for the other trait are presented in Table 3. The genotypes that presented the best GCA estimates for Brix % were SP81-3386, SP81-1763 and RB845257. SP86-172 exhibited the smallest GCA estimate for Brix % but the largest for TCH along with SP84-2029 (plant cane) and RB845257 (ratoon).

The contrasting behavior of SP86-172 may be explained by the negative correlation exhibited between these traits and their components in some studies (Brown et al., 1969; Mariotti, 1972). This contrasting behavior was also observed in SP84-2029.

With regard to rust reaction, the largest GCA was observed with SP81-1763 and SP79-3314. It should be pointed out that in this trait, as well as in pithiness, the grades are inverted, that is, smaller grades are attributed to more favorable genotypes.

Stalk number is highly correlated to yield (Bressiani, 1993). Therefore, it is not surprising that genotypes that exhibit large GCA for one of these traits, also do so for the other. Table 3 shows that genotypes SP86-

Table 2. Analysis of variance according the diallel design, model IV, proposed by Griffing, 1956. Traits evaluated in Plant (1) and Ratoon(2) cane.

Variation	GL	Brix% (1º, 2ºC)	TCH 1°C	TCH 2°C	TBH 1°C	TBH 2°C	# Stalk	Rust	Pith
Blocks	3	3.291 [1/]	1,830.279	1,213.721	8.548	74.706	7.256	12.454	0.124
Treatments	27	1.385 [1/]	263.596 [1/]	223.469 [1/]	8.707 [1/]	8.645 [1/]	1.34 [1/]	800.261 [1/]	0.028 [1/]
CGC	7	3.017 [1/]	562.284 [1/]	621.411 [1/]	5.925 [1/]	22.519 [1/]	3.408 [1/]	2,529.297 [1/]	0.073 [1/]
CEC	20	0.081 [1/]	158.97 [1/]	84.173	3.036 [1/]	3.706	0.619	195.083 [1/]	0.012
Error	81	0.333	53.06	54.577	1.202	2.281	0.373	47.774	0.008
CV%		16.97	9.83	10.27	11.12	10.19	9.14	19.18	9.26
Mean		3.78	74.08	71.92	9.87	14.82	6.68	36.03	0.98
GCA prop.		0.6250	0.6114	0.7686	0.4672	0.7322	0.7123	0.8537	0.7363

[1/] Significance at ($p<0{,}01$); Brix % (1º, 2ºC) – Brix % juice in the combined analysis from plant cane and first ratoon; TCH 1C - Tons cane per hectare in plant cane; TCH 2C - Tons cane per hectare in ratoon; TBH 1C - Tons Brix per hectare in plant cane and TBH 2C - Tons Brix per hectare in ratoon.

Table 3. Estimates of general combining ability for six traits evaluated in plant cane and/or ratoon, in a complete diallel.

#	Parents	Brix %	TCH 1ºC	TCH 2ºC	TBH 1ºC	TBH 2ºC	# Stalk	Rust	Pith
1	RB845257	0.202 [1/]	-3.657 [1/]	3.486 [1/]	-0.290	0.852 [1/]	0.332 [1/]	-3.258 [1/]	0.026
2	SP86-172	-0.529 [1/]	9.990 [1/]	9.976 [1/]	0.911 [1/]	1.645 [1/]	0.292 [1/]	-0.962	0.113 [1/]
3	SP79-3314	-0.043	-0.770	-2.694	-0.070	-0.623 [1/]	-0.636 [1/]	14.235 [1/]	0.005
4	SP80-1607	0.071	-5.580 [1/]	-5.796 [1/]	-0.690 [1/]	-1.151 [1/]	0.006	-1.057	0.031
5	SP81-1763	0.182 [1/]	-0.702	-0.929	-0.005	-0.013	0.131	15.042 [1/]	-0.045 [1/]
6	SP81-3386	0.257 [1/]	-0.794	-1.888	-0.118	-0.006	-0.156	-3.837 [1/]	-0.012
7	SP84-2029	-0.027	3.658 [1/]	2.238	0.505 [1/]	0.414	0.435 [1/]	-16.333 [1/]	-0.107 [1/]
8	F154	-0.114	-2.144	-4.393 [1/]	-0.247	-1.118 [1/]	-0.403 [1/]	-3.830 [1/]	-0.010
	$\widehat{var}(\hat{g}_i)$	0.00607	10.935	19.898	0.0438	0.0832	0.0136	17.418	0.0003

[1/] $p<0.05$ by t test; TCH 1ºC – Tons cane peer hectare in plant cane; TCH 2ºC – Tons cane per hectare in ratoon; TBH 1ºC - Tons Brix per hectare in plant cane and TBH 2ºC - Tons Brix per hectare in ratoon.

172 and SP84-2029 are among the best. Three genotypes exhibited significant GCA estimates for pithiness: SP86-172, SP81-1763 and SP84-2029.

Estimates of specific combing ability are presented in Table 4. For SCA, a non-significant value (i.e. similar to zero) indicates that progeny is best evaluate by the GCA of both parents. Significant values indicate that the progenies can be significantly better or worst than expected from the GCA of both parents (Cruz and Regazzi, 1997).

GCA analysis for Brix % was most favorable for genotypes SP86-172 and SP84-2029. SCA analysis did not point out any cross involving these parents. The cross between the genotypes SP81-1763 and SP81-3386, which individually showed large and positive GCA estimates for Brix % but non significant for TCH, exhibited the greatest SCA for TCH (plant) and TBH (plant and ratoon).

The genotype SP84-2029, which exhibited positive significant ($p<0.05$) GCA for stalk number, exhibited the best SCA when crossed with F154, which individually exhibited negative GCA for the same trait. SP84-2029 exhibited smaller SCA when crossed with RB845257, which exhibited GCA positive ($p<0.05$).

On the other hand, the cross between SP81-3386 and F154 presented the worst SCA estimate for TCH, with parents showing negative estimates for GCA.

Every time that the GCA is more important than the SCA, parents must be chosen based on the value of general combining ability of genotypes. This work showed that the GCA was the most significant all the time, which asks for the recommendation that, for the genotypes evaluated, parents selection must first be based on the GCA followed by the SCA within genotypes of high GCA.

Table 4. Estimate of specific combining ability for six traits evaluated in plant and/or ratoon for a complete diallel.

M	F	Brix %	TCH 1ºC	TCH 2°C	TBH 1ºC	TBH 2ºC	# Stalk	Rust	Pith
1	2	0.187	-10.169 [1/]	-3.364	-1.383 [1/]	-0.320	0.363	1.601	-0.030
1	3	0.476 [1/]	0.681	0.866	0.451	0.458	0.092	1.235	0.069
1	4	-0.313	3.111	-0.852	0.190	-0.403	0.430	-0.324	0.028
1	5	-0.001	-0.737	9.041 [1/]	-0.075	1.838 [1/]	0.345	-4.212	0.011
1	6	0.026	5.565	-2.031	0.734	-0.388	0.052	-2.304	0.056
1	7	-0.197	1.633	0.185	0.095	-0.148	-0.790 [1/]	6.643 [1/]	0.001
1	8	-0.178	-0.085	-3.846	-0.013	-1.037	-0.492	-2.640	-0.056
2	3	0.281	-0.485	1.526	0.017	0.645	-0.208	-4.712	0.002
2	4	0.001	4.845	2.588	0.557	0.643	0.060	-1.490	0.086 [1/]
2	5	-0.419 [1/]	2.256	-1.319	-0.108	-0.545	-0.305	-12.399 [1/]	0.032
2	6	-0.119	0.438	0.240	0.390	-0.432	-0.028	7.390 [1/]	-0.081 [1/]
2	7	0.116	-0.104	0.355	0.152	0.038	0.590 [1/]	-2.373	-0.056
2	8	-0.048	3.218	-0.026	0.374	-0.030	-0.472	11.983 [1/]	0.047
3	4	-0.144	-2.155	-1.502	-0.480	-0.298	-0.092	-2.947	-0.036
3	5	0.146	6.636 [1/]	-1.929	1.075 [1/]	-0.367	0.033	19.285 [1/]	-0.030
3	6	-0.330	-0.222	0.420	-0.276	-0.143	-0.131	-0.447	-0.003
3	7	0.230	-6.964 [1/]	-6.186 [1/]	-0.635	-1.243	0.029	-3.860	-0.068
3	8	-0.659 [1/]	2.508	6.805 [1/]	-0.153	0.948	0.277	-8.554 [1/]	0.066
4	5	-0.044	-12.504 [1/]	-1.807	-1.675 [1/]	-0.448	0.022	1.866	-0.066
4	6	0.031	-1.792	-3.629	-0.326	-0.675	0.028	1.175	-0.030
4	7	-0.259	3.416	2.756	0.335	0.335	-0.183	-0.149	0.056
4	8	0.727 [1/]	5.078	2.446	1.397 [1/]	0.847	-0.265	1.868	0.019
5	6	0.146	9.800 [1/]	5.455	1.299 [1/]	1.397 [1/]	0.173	-0.654	0.107 [1/]
5	7	0.130	-2.412	-6.851 [1/]	-0.250	-1.293 [1/]	-0.328	-0.147	-0.018
5	8	0.041	-3.040	-2.591	-0.268	-0.582	0.060	-3.740	-0.015
6	7	0.055	-0.840	6.038	-0.091	1.350 [1/]	-0.151	-3.179	0.049
6	8	0.191	-12.949 [1/]	-6.492 [1/]	-1.730 [1/]	-1.108	0.057	-1.982	-0.098 [1/]
7	8	-0.074	5.270	3.703	0.392	0.962	0.834 [1/]	3.065	0.037
$v\hat{a}r(\hat{s}_{ij})$		0.02973	9.475	97.459	0.2146	0.4073	0.0666	85.311	0.00146

M =male, F =female - 1 - RB845257, 2 - SP86-172, 3 - SP79-3314, 4 - SP80-1607, 5 - SP81-1763, 6 - SP81-3386, 7 - SP84-2029, e 8 - F154; [1/] $p<0.05$ by t test; TCH 1ºC – Tons cane per hectare in plant cane, TCH 2ºC – Tons cane per hectare in ratoon; TBH 1ºC - Tons Brix per hectare in plant cane; TBH 2ºC - Tons Brix per hectare in ratoon.

CONCLUSIONS

This work permitted the following conclusions:

For the group of genotypes studied, general combining ability was more important than specific combining ability for all traits.

Genotypes SP86-172 and SP84-2029 exhibited the best GCA for TBH, while SP80-1607 and F154 exhibit the poorest values. SP86-172, however exhibited the poorest GCA for Brix % and for pithiness.

The cross between the genotypes SP81-1763 and SP81-3386 exhibited the best SCA for TCH (plant) and for TBH (plant and ratoon). These genotypes exhibited positive and significant GCA estimates for Brix % but negative, albeit non-significant, estimates for TCH and TBH.

As the group of genotypes studied is fixed, these results cannot be extrapolated to other groups of genotypes. However, given the greater proportion of GCA in relation to SCA, it is valid to conclude that parental selection should initially be based on GCA. Next, one cross may be chosen to select among those based on their SCA. With this strategy, however, one may lose combinations with exceptionally high SCA.

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RESUMO

Capacidade de combinação em oito clones selecionados de cana (*Saccharum* Sp)

Oito genótipos híbridos de cana-de-açúcar, oriundos do banco de germoplasma da Copersucar, foram cruzados em um esquema de cruzamentos dialélicos de Griffing, modelo IV. Cinco caracteres foram avaliados em um e/ou dois cortes na progênie: Brix %, tonelagem de cana por hectare (TCH), n.º de colmos industrializáveis, incidência de ferrugem e nível de isoporização. Um sexto caráter, tonelagem de Brix % por hectare (TBH) foi calculado com o teor de Brix % e o TCH. A capacidade geral de combinação (CGC) foi significante para todos os caracteres avaliados ($p<0,01$); a capacidade específica de combinação (CEC) foi significativa para os caracteres Brix %, TCH, TBH e para a incidência de ferrugem na cana planta. A proporção relativa da CGC, que mede a razão entre a CGC e a CEC, foi superior a 0,60 para todas as variáveis exceto para o TBH em cana planta, indicando predomínio da CGC. A orientação para a seleção de genótipos com base primeiramente na CGC para que, em seguida, combinações híbridas entre genótipos com alta CGC possam ser realizadas com o propósito de se explorar a CEC é válida, porém não impede que sejam perdidas combinações com alta CEC.

REFERENCES

Baker, R.J. 1978. Issues in diallel analysis. Crop Science. 18:533-536.

Balance, M.C; Ramos, N.M. and Mesa-Lopes, J.M. 1996. Diallelic analyses of resistance of five sugarcane parents to *Ustilago scitaminea* Sydow. p.340-345. In: Proceedings of International Society of Sugar Cane Technologists Congress, 22nd, Cartagena, 1995. Tecnicaña, Cali.

Bressiani, J.A. 1993. Herdabilidade e repetibilidade dos componentes da produção na cultura da cana-de-açúcar. M.S. Thesis. Universidade de São Paulo, Piracicaba.

Brown, A.H.D.; Daniells, J. and Latter, B.D.H. 1969. Quantitative genetics of sugarcane. II - Correlation analysis of continuous characters in relation to hybrid sugarcane. Theoretical and Applied Genetics. 39:1-10.

Cockerham, C.C. 1963. Estimation of genetic variances. Statistical Genetics and Plant Breeding. 982:53-93.

Cruz, C.D. and Regazzi, A.J. 1997. Modelos biométricos aplicados ao melhoramento genético. Universidade Federal de Viçosa, Viçosa.

Dinardo-Miranda, L.L. 1990. Avaliação de progenitores de cana-de-açúcar para resistência ao *Meloidogyne javanica.* Boletim Técnico Copersucar. 50:11-12.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Sciences. 9:463-493.

Hogarth, D.M. 1980. The effects of accidental selfing on the analysis of a diallel cross with sugar cane. Euphytica. 29:737-746.

Hogarth, D.M. 1987. Genetics of sugarcane. p.255-272. In: Don J. Heinz (Org.). Sugarcane improvement through breeding. Developments in crop science. 11.ed. Elsevier, Amsterdam.

Killick, R.J. 1977. Genetic analyses of several traits in potatoes by means of a diallel cross. Annals of Applied Biology. 86:279-282.

Machado Junior, G.R.; Walker, D.I.; Bressiani, J.A. and Da Silva, J.A.G. 1996. Emasculation of sugarcane tassels using hot water. p.346-352. In: Proceedings of the International Society of Sugar Cane Technologists Congress, 22nd, Cartagena. Tecnicaña, Cali.

Mariotti, J.A. 1972. Associations among yield and quality components in sugarcane hybrid progenies. p.297-302. In: Proceedings of the International Society of Sugar Cane Technologists Congress, 14th, New Orleans. Franklin Press, Baton Rouge.

Miller, J.D. 1977. Combining ability and yield component analysis in a five parent diallel cross in sugarcane. Crop Science. 17:545-547.

Miranda Filho, J.B. and Geraldi, I.O. 1984. An adapted model for the analysis of partial diallel crosses. Revista Brasileira de Genética. 7:667-688.

Nunes Junior, D.; Giacomini, G. and Oliveira, A.A. 1982. Comparação do florescimento, isoporização e qualidade tecnológica em duas variedades de cana-de-açúcar na presença de maturador. Boletim Técnico Copersucar. 20:20-31.

Ortiz, R.; Cruz, R.; Caballero, A. and Alvarez, M. 1994. Evaluación de progenitores para los programas de resistência a la roya (*Puccinia melanocephala* H y P Sydow) em las provincias orientales. Cultivos Propicales. 15:90-93.

Peixoto, T.C.; Ricci Junior and Amorim, L. 1988. Avaliação de progenitores de cana-de-açúcar quanto à reação ao vírus do mosaico em cruzamento dialélico. Boletim Técnico Copersucar. 40:29-31.

Purdy, L.H. and Dean, J.L. 1981. A system for record data about sugarcane rust/host interactions. Sugar Cane Pathology Newsletter. 27:35-40.

Rumbaugh, M.D.; Caddel, J.L. and Rowe, D.E. 1988. Breeding and quantitative genetics. p.777-807. In: Hanson, A.A.; Barnes, D.K. and Hill Jr, R.R. (Orgs.). Alfalfa and alfalfa improvement. Madison.

Sprague, G.F. and Tatum, L.A. 1942. General and specific combining ability is single crosses of corn. Journal of the American Society of Agronomy. 34:923-932.

Wu, K.K.; Heinz, D.J.; Meyer, H.K. and Ladd, S.L. 1980. Combining ability and parental evaluation in five selected clones of sugarcane. Theoretical and Applied Genetics. 56:241-244.

Yang, T.C. and Chu, C.C. 1962. Evaluation of combining ability in sugarcane (Part 1). Report of Taiwan Sugar Experimental Station. 26:1-10.

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