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Combining ability and heterosis for disease index of red rot in sugarcane (*Saccharum officinarum* L.)

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Abstract

Combining ability and heterosis for disease index of red rot were studied in the progenies of nine sugarcane (*Saccharum officinarum* L.) clones to identify suitable parents and crosses for further exploitation in breeding programmes. Based on the combining ability results, Co 8347, ISH-021 and Co 86011 were identified as good general combiners for imparting red rot resistance. Use of these clones, with high (negative) *gca* effects, would be advantageous in poly cross method of breeding. The association between *sca* effects and heterosis over mid-parent indicated that the *sca* effects were not so prominent to cause unidirectional heterosis. Hence, *per se* performance, *sca* effects and heterosis were considered to identify Co 7201 × Co 86011, Co 8347 × Co 1148, Co 89009 × Co 86011 and ISH-021 × Co 1148 as the best specific combinations for red rot disease index. Both additive and dominance variances were equally important and heritability (in narrow sense) was 0.51 for red rot resistance in sugarcane. High value (0.97) of heritability (in broad sense) indicated the negligible influence of environment on red rot disease development in sugarcane.

Key words: Sugarcane, combining ability, red rot, resistance, disease index

Introduction

Red rot, caused by the fungus *Colletotrichum falcatum* Went, is the major disease of sugarcane in India. Many good varieties like Co 312, Co 313, Co 453, Co 658, Co 997, Co 1148, Co 7717, CoC 671, BO 17, CoS 510, CoJ 64 etc. went out of cultivation due to their susceptibility to red rot disease. Use of resistant varieties is the most effective means of controlling red rot. However, little is known about the genetics of resistance to red rot [1]. Data available from a large number of crosses made at Coimbatore and elsewhere showed that crosses involving resistant parents gave a high percentage of resistant or moderately resistant progenies. However, resistant progenies were also obtained from crosses involving susceptible parents. These results indicate the importance of additive and certain interaction components, and incorporation of resistant parents will help in building up a source population.

The theory of quantitative genetics may not be applicable in sugarcane as its assumptions like regular diploid inheritance, random mating population, no epistasis, no linkage and no maternal effect may not be satisfied. However, Hogarth [2] studied the effect of the violation of these assumptions and concluded that violation of these assumptions didn't have serious effects on estimation of genetic parameters.

The incorporation of new germplasm into commercial clones is a slow process, and the breeding population is made up largely of advanced backcross lines and their derivatives. The combining ability analysis helps in assessing the relative magnitude of these actions. Line × tester analysis has been used to evaluate parents for their general and specific combining ability [3-4]. The present investigation was undertaken to study the general and specific combining ability effects of nine sugarcane clones for red rot resistance with the aim to identify suitable parents and crosses for further exploitation in breeding programmes.

Materials and methods

The experimental material consisted of 5 lines (females), 4 testers (males) and progenies of their 20 crosses effected in line × tester mating design. Parents, their red rot disease index and red rot rating are presented in Table 1. Twenty progenies each of the 20 crosses along with the 9 parental clones were evaluated in RBD with 3 replications. Each clone was grown in a 2m long plot spaced at 75cm apart. Normal cultural practices were followed to raise a good crop.

Stalks were inoculated with a mixture of 5 identified races Cf01 (Co 1148), Cf02 (Co 7717), Cf03 (CoJ 64), Cf07 (CoJ 64) and Cf09 (CoS 767) during the 2nd week of August by plug method [5]. The field was irrigated on the next day of inoculation. The relative humidity was between 75 to 90 % during the incubation period. The minimum and maximum temperature ranged from 22-26°C and 31-34°C, respectively. Observations on disease infection were recorded 60 days after

Table 1. Red rot rating, mean performance (x) and general combining ability effects for disease index of lines and testers used in the study

S.No.	Parent	Disease rating	Disease index	($\bar{x}$)	*gca*
Lines					
1.	Co 7201	MR	4.0	4.00	0.86*
2.	Co 8347	MR	3.0	2.90	–0.46*
3.	Co 89009	S	6.2	6.21	0.44*
4.	ISH-021	MS	5.6	5.61	–0.85*
5.	ISH-100	S	6.5	6.50	0.01
Testers					
1.	Co 1148	HS	9.0	8.93	0.41*
2.	Co 62198	MR	4.0	3.99	0.63*
3.	Co 86011	S	6.6	6.60	–1.39*
4.	Co 89003	MR	3.0	3.02	0.34*

inoculation. The reaction of each clone was recorded by following the internationally accepted 0-9 scale [6]. The cross means were utilized for combining ability (Line × Tester) analysis as suggested by Singh and Chaudhary [7].

Results and discussion

The analysis of variance (Table 2) indicated significant differences among lines, testers and line × tester interaction for red rot disease index. Contribution of testers to the total variance was the highest (41.81 %) followed by that of line × tester (34.26 %) and lines (23.93 %). The lower contribution of lines indicated that selection of testers (male parents) with superior *per se* performance would be advantageous than the selection of superior female parents. This finding is contradictory to many studies for yield and quality traits. Loh and Tseng [8] reported that sucrose content might depend on seed parent. Rai *et al.* [3] also reported higher contribution of lines than that of line × tester to the total variance for NMC, cane length, cane diameter, SCW and stool weight.

Among the lines, Co 8347 and ISH-021 exhibited significant desirable *gca* effects for disease index (Table 1). But the *gca* effects of Co 7201 and Co 89009 were positive, which is undesirable. The *gca* effects of all the testers were significant. However, it was desirable only in case of Co 86011. This indicated that of the 9 parents studied only Co 8347, ISH-021 and Co 86011 were good general combiner for red rot resistance. Co 86011 (S) and ISH-021 (MS) showed high negative *gca* effects inspite that they were susceptible and moderately susceptible, respectively. This might be due to existence of other form of resistance (probably horizontal) that is inherited to the progenies apart from race specific resistance.

Table 2. Analysis of variance for combining ability for disease index of red rot

Source of variation	df	Mean sum of squares for disease index	Contribution to the total variance by		
			Lines	Testers	Line × tester
Lines	4	5.62**	23.93	41.81	34.26
Testers	3	13.11**			
Line × tester	12	2.68**			
Error	38	0.01			

Significant *sca* effects were observed in all the crosses except in ISH-100 × Co 89003 (Table 3). However, only 10 crosses showed desirable (negative) *sca* effects. The cross Co 89009 × Co 89003 (S × MR) was the best specific combiner. The next important specific combination was Co 7201 × Co 86011 (MR × S) followed by Co 8347 × Co 1148 (MR × HS), Co 7201 × Co 62198 (MR × MR), Co 8347 × Co 62198 (MR × MR), ISH-100 × Co 62198 (S × MR), Co 89009 × Co 86011 (S × S), ISH-021 × Co 89003 (MS × MR), ISH-021 × Co 62198 (MS × MR) and ISH-021 × Co 1148 (MS × HS). Hence, these crosses may be exploited specifically for red rot resistance. Of the above 10 selected crosses, 6 crosses had atleast one susceptible/highly susceptible parent. Occurrence of resistant progenies from susceptible parents might be due to the presence of significant levels of race non-specific (horizontal) resistance. Other 10 crosses were poor specific combiners for red rot resistance.

Heterosis varied from –1.62 to 4.99 in different crosses (Table 3). However, desirable type of heterosis was observed only in 8 crosses. The Cross ISH-021 × Co 1148 showed the highest desirable heterosis for red rot resistance followed by ISH-100 × Co 86011, ISH-021 × Co 86011, Co 89009 × Co 86011, ISH-100 × Co 1148, Co 7201 × Co 86011, Co 8347 × Co 1148 and Co 89009 × Co 1148.

Table 3. Mean performance ($\bar{x}$), specific combining ability effects (*sca*) and heterosis (h) over mid-parent of crosses for red rot disease index in sugarcane

Crosses	$\bar{x}$	*sca*	h
Co 7201 × Co 1148	8.19	0.64*	1.73*
Co 7201 × Co 62198	7.18	–0.60*	3.19*
Co 7201 × Co 86011	4.70	–1.50*	–0.60*
Co 7201 × Co 89003	8.50	1.01*	4.99*
Co 8347 × Co 1148	5.44	–0.79*	–0.48*
Co 8347 × Co 62198	5.96	–0.49*	2.52*
Co 8347 × Co 86011	4.89	0.47*	0.14
Co 8347 × Co 89003	6.97	0.81*	4.01*
Co 89009 × Co 1148	7.37	0.24*	–0.20*
Co 89009 × Co 62198	9.00	1.65*	3.90*
Co 89009 × Co 86011	5.00	–0.33*	–1.40*
Co 89009 × Co 89003	5.50	–1.56*	0.89*
ISH-021 × Co 1148	5.64	–0.19*	–1.62*
ISH-021 × Co 62198	5.84	–0.22*	1.04*
ISH-021 × Co 86011	4.71	0.67*	–1.40*
ISH-021 × Co 89003	5.52	–0.25*	1.20*
ISH-100 × Co 1148	6.80	0.10*	–0.91*
ISH-100 × Co 62198	6.58	–0.34*	1.34*
ISH-100 × Co 86011	5.14	0.24*	–1.41*
ISH-100 × Co 89003	6.62	–0.01	1.86*

The perusal of heterosis and sea values at a time for different crosses indicated that the crosses Co 7201 × Co 86011, Co 8347 × Co 1148, Co 89009 × Co 86011 and ISH-021 × Co 1148 have shown significant negative values. In other words, the *sca* effects have resulted in producing heterotic effects in only these 4 crosses. This is supported by low correlation (Table 4) between *sca* effects and heterosis over mid-parent, i.e. 0.37. The additive genetic variance was the maximum (0.99) followed by dominance variance (0.89) (Table 4). The ratio of additive genetic variance in relation to dominance variance was 1.11. These results indicated that additive genetic variance and dominance genetic variance were equally important for disease index.

The heritability for disease index in narrow sense (0.51) and in broad sense (0.97) was quite high. This indicated the reliability of disease index in parental selection for hybridization. High heritability value, in broad sense, (0.97) also indicated a narrow difference between phenotypic and genotypic variances. Hence, the effect of environment on red rot disease development was negligible. It is expected to be so because the progenies were evaluated by plug method of inoculation.

Correlation coefficients between a pair of genetic parameters are presented in Table 4. Low degree of association was observed between line (*per se*) and hybrid performance of females. This indicated that selection of resistant female parents might not result in high degree of red rot resistance in progeny population. The association between *gca* and parents (*per se*) was negative. This indicated that parents (*per se*) did not contribute to *gca* effects. The association between sea and performance of crosses was 0.59. However, the association between *sca* effects and heterosis over mid-parent was only 0.37. This indicated that the *sca* effects were not so prominent to cause unidirectional heterosis over mid-parent.

Table 4. Genetic parameters and correlation coefficients between genetic parameters for red rot disease index in sugarcane

Parameters	Disease index	Correlation coefficients between genetic parameters			
		Line (*per se*) & hybrid performance of females	*sca* and hetrosis over mid parent	*sca* and crosses	*gca* and parents (*per se*)
σ^2_A	0.99				
σ^2_D	0.89	0.03	0.37	0.59	-0.15
h^2_{ns}	0.51				
h^2_{bs}	0.97				
σ^2_A/σ^2_D	1.11				

The choice of proper parental clone for imparting red rot resistance to their progenies is of great importance for success in sugarcane improvement programme. Though the performance of such clones themselves gives some indication regarding their usefulness, the long-term potentialities are least known at the beginning of a breeding program. This is supported by low correlations between line (*per se*) and hybrids. Similarly, the correlation value between *gca* and parents (*per se*) was also low. This clearly indicated that the *per se* performance of parents cannot be the only criterion of selection of parents for hybridization for incorporating red rot resistance. Based on *per se* performance and *gca* effects of clones, Co 8347, ISH-021 and Co 86011 were identified as good general combiners. The use of these parents, with high *gca* effects, would be advantageous in poly cross method of breeding. The perusal of heterosis and *sca* values for different crosses helped in isolation of Co 7201 × Co 86011, Co 8347 × Co 1148, Co 89009 × Co 86011, and ISH-021 × Co 1148 as elite crosses for red rot resistance. Occurrence of resistant progenies from susceptible parents and high negative *gca* effects of Co 86011 and ISH-021 (susceptible and moderately susceptible clones, respectively) indicated the presence of race non-specific (horizontal) resistance. Horizontal resistance is due to additive genetic effects, which would be stable.

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