Inheritance of Resistance to Pokkah Boeng in Sugarcane Crosses

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ABSTRACT

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Severity of natural infection of sugarcane by the pokkah boeng organism (*Gibberella moniliformis*) was estimated for 40 populations of sugarcane grown in a randomized block with six replications. The 40 populations consisted of 25 F_1 populations from five males × five females, ten vegetatively-propated parental populations, and five S_1 populations from selfed male parents. Heritability estimates for disease reaction were very high, indicating that genetic differences among populations were responsible for most of the observed differences in pokkah boeng reaction. This study indicates that the frequency of pokkah boeng susceptibility within F_1 populations can be accurately predicted if the degree of susceptibility of the parental clones is known.

Additional key words: *Saccharum* sp., heritability, breeding value, *Gibberella moniliformis*.

Pokkah boeng, which is a potentially destructive disease of sugarcane (*Saccharum* sp. L.) caused by *Gibberella moniliformis* (Sheldon) Wineland, is present in most, if not all sugarcane producing areas of the world (2). The fungus can persist saprophytically on plant residues, and is disseminated mainly by airborne spores. In infected sugarcane plants, the symptoms are: chlorotic areas at the base of young leaves; distortion and shortening of affected leaves; and, in acute cases, stalk death.

Pokkah boeng is controlled by the use of resistant cultivars. Thus, sugarcane breeders are forced to discard a portion of their otherwise promising clones due to pokkah boeng susceptibility. Complete elucidation of character inheritance in sugarcane is difficult because of the genetic complexity and high polyploidy of the crop. However, populations from different crosses differ with respect to frequency of plants susceptible to pokkah boeng, and this indicates that susceptibility is genetically inherited. The purpose of this experiment was to study the inheritance of pokkah boeng susceptibility in 25 sugarcane crosses. The specific objective was to determine the extent to which susceptible parents produced susceptible progenies and resistant parents, resistant progenies.

MATERIALS AND METHODS

Twenty-five F_1 populations were produced by crossing five sugarcane clones used as females with five used as males (Table 1). The male clones also were self-pollinated to produce five S_1 populations. All parents were complex *Saccharum* hybrids of the type planted commercially by the Florida sugarcane industry.

In January, 1975, hybrid seeds from each of the 25 crosses and selfed seeds from the male parents were planted in greenhouse flats. At the same time, a clonal population from each of the 10 parents was started from vegetative propagules in greenhouse flats. Vegetative propagules consisted of small wedges cut from the nodes of mature stalks in such a way that each bore a shoot bud and a number of root primordia. Plants were transplanted from germination flats to peat pots in March, and on 26 April they were planted in an experimental field at Canal Point.

The experimental design was randomized complete blocks with six replications. Each block contained the 40 treatments or populations (25 F_1 populations + 10 clonal parental populations + five S_1 populations). Individual plots consisted of 17 plants from a particular population spaced at 1-m intervals in a row. Rows were 1.5 m apart. The test plants were bordered by guard rows on each side.

Throughout the growing season, plants were exposed to air-borne spores produced within the plot area. Disease readings were made between 18 and 29 September and those for each replication were completed on a single day. Each of the 240 plots in the test (40 populations × six replications) was given an overall disease score based on the formula: (percentage of plants in plot showing mild pokkah boeng symptoms) + 2 (percentage of plants showing severe symptoms).

Three analyses of variance were made: One for the 25 F_1 populations, one for the 10 clonal parent populations, and one for the five S_1 populations. Duncan's new multiple range test (4) was used to compare population means. The fraction of the variation in pokkah boeng damage attributable to genetic differences among

TABLE 1. Pokkah boeng infection ratings[a] for parents and 25 F_1 sugarcane populations produced by crossing five males × five females. Lowest numbers indicate the greatest resistance

Male parent	Male clonal	Male selfs	Mean of all F_1 populations	Mean of F_1 population: Male X Female parent				
				CP 52-68	CP 61-37	CP 68-1067	CP 62-374	NCO-310
CP 70-300	5.9 a[b]	16.7 a	11.4 a	4.9 aw	9.1 aw	11.8 aw	8.8 aw	22.5 aw
CP 63-588	11.6 a	20.8 a	17.6 ab	13.7 abw	17.2 aw	9.3 aw	25.9 abw	21.9 aw
CP 66-346	13.7 a	17.4 a	13.1 ab	10.8 abwx	5.4 aw	13.8 awx	10.8 awx	24.5 ax
CP 57-526	42.9 b	28.2 a	20.3 bc	24.8 bwx	11.1 aw	11.9 aw	17.6 aw	36.0 ax
CP 57-614	97.1 c	66.5 b	25.8 c	10.2 abw	19.2 awx	23.6 awx	41.6 bx	34.4 ax
Column means	34.2 z	29.9 z	17.6 wx	12.9 wx	12.4 w	14.1 wx	20.9 xy	27.9 yz
Female clonal values:				1.0 x	1.0 x	17.6 xy	29.2 xy	41.5 y

[a]Values in this table were calculated separately for each of the six blocks before averaging. Consequently, some values differ slightly from those suggested by Table 2 where percentages were tabulated for the entire test without regard to replication differences.
[b]Significant differences between means are indicated by: a,b,c: Duncan's multiple range test within columns. wxyz: Duncan's multiple range test within rows. Values not followed by a common letter are significantly different, $P = 0.05$.

TABLE 2. Number and percent of sugarcane plants in parental, F_1, and S_1 populations which showed mild or severe pokkah boeng symptoms

Parent clone number	Parent clone name	Plants with pokkah boeng symptoms: Number			Percent		
		None	Mild	Severe	None	Mild	Severe
1	CP 70-300	96	4	1	95.0	4.0	1.0
2	CP 63-588	83	11	0	88.3	11.7	0.0
3	CP 66-346	78	11	1	86.7	12.2	1.1
4	CP 57-526	52	30	6	63.3	30.6	6.1
5	CP 57-614	24	57	21	23.5	55.9	20.6
6	CP 52-68	98	1	0	99.0	1.0	0.0
7	CP 61-37	92	1	0	98.9	1.1	0.0
8	CP 68-1067	84	12	3	84.9	12.1	3.0
9	CP 62-374	67	27	1	70.5	28.4	1.0
10	NCO 310	21	14	1	58.3	38.9	2.8
F_1 populations from crosses between parents:							
6 × 1		96	5	0	95.0	5.0	0.0
6 × 2		89	10	2	88.1	9.9	2.0
6 × 3		91	11	0	89.2	10.8	0.0
6 × 4		49	9	4	79.0	14.5	6.5
6 × 5		90	10	0	90.0	10.0	0.0
7 × 1		89	5	2	92.7	5.2	2.1
7 × 2		86	7	5	87.8	7.1	5.1
7 × 3		90	3	1	95.7	3.2	1.1
7 × 4		90	9	1	90.0	9.0	1.0
7 × 5		77	16	1	81.9	17.0	2.0
8 × 1		92	6	3	91.1	5.9	3.0
8 × 2		89	5	2	92.7	5.2	2.1
8 × 3		88	10	2	88.0	10.0	1.0
8 × 4		90	10	1	89.1	9.9	1.0
8 × 5		82	12	6	82.0	12.0	6.0
9 × 1		90	7	1	91.8	7.2	1.0
9 × 2		76	20	3	76.8	20.2	3.0
9 × 3		80	9	1	88.9	10.0	1.1
9 × 4		57	9	2	83.8	13.2	2.9
9 × 5		62	29	5	64.6	30.2	5.2
10 × 1		81	19	2	79.4	18.6	2.0
10 × 2		80	15	3	81.6	15.3	3.1
10 × 3		81	15	5	80.2	14.9	4.9
10 × 4		68	22	7	70.1	22.7	7.2
10 × 5		70	27	4	69.3	26.7	4.0
S_1 populations from selfing parent number							
1		72	12	1	84.7	14.1	1.2
2		80	14	3	82.5	14.4	3.1
3		73	15	0	83.0	17.0	0.0
4		53	13	2	79.1	17.0	3.0
5		45	41	12	45.9	41.9	12.2

populations (broad-sense heritability) was estimated from the analysis of variance according to the following formulas: $V_e + rV_g$ = the expectation of the clone mean square, V_e = the expectation of the error mean square, V_g = the total genetic variance, and r = 6 = the number of replications per clone. Heritability in the broad sense was defined as V_g/V_p, where $V_p = V_g + V_e/r$. Estimates of narrow-sense heritability were obtained in three ways (1): (i) by doubling the correlations between pokkah boeng readings of F_1 populations and those of the male parents; (ii) by doubling the correlation between F_1 populations and female parents; and (iii) by correlating F_1 scores with the average scores of the male and female parents.

The "breeding value" of each parental clone for pokkah boeng susceptibility was estimated in terms of the above-average or below-average incidence of the disease in the F_1 populations from that parent according to the formula (3): Breeding value of a clone = 2 (Mean score of all populations where the clone was a parent − mean score of all populations).

RESULTS AND DISCUSSION

The 10 parents showed a wide range of disease reactions as indicated by disease scores and by percentages of infected plants in the clonal plots (Tables 1 and 2). Parents CP 52-68 and CP 61-37 were most resistant, having mean disease scores of 1.0, whereas CP 57-614 (score 97.1), CP 57-526 (42.9), and NCO 310 (41.5) were the most susceptible. The overall mean score for the 10 parents (26.1) was higher than the mean for the 25 F_1 populations (17.6). This result seems surprising, because one might expect selected commercial cultivars to have greater pokkah boeng resistance than nonselected seedlings. The likely explanation is that pokkah boeng susceptibility tends to be associated with large stalk diameter and *Saccharum officinarum* plant form. Most nonselected seedlings tend to be thin-stalked and, in growth habit, they more closely resemble their highly-resistant wild ancestors, *S. spontaneum* and *S. barberi*, than do commercial selections.

In general, parental clones behaved very consistently with respect to pokkah boeng in the clonal plots, S_1 plots, and F_1 hybrid plots (Table 3). In Table 3, male clones are ranked from 1 (least susceptible) to 5 (most susceptible) in crosses with each of the five females, in clonal plots, and in S_1 plots. Females are ranked according to their performance in clonal plots and according to their performance with each of the five males.

The cultivar, CP 70-300, was the most resistant male parent in the clonal plots. It also produced the most resistant selfed population and the most resistant F_1 population with two of the five females. With the other three females, its F_1 populations ranked second in resistance. Similarly, CP 57-614 was the most susceptible male parent in the clonal plots (Table 3). It produced the most susceptible selfed population and, with three of the five females, it produced the most susceptible F_1 populations. Its F_1 population with female NCO 310 was also quite susceptible and received a rank of 4.

Female parents also performed rather consistently in the crosses and clonal plots. Parent NCO 310 was highly susceptible, and CP 52-68 and CP 61-37 were rather resistant.

The close agreement in the performance of parental cultivars in clonal S_1, and F_1 populations indicates that the pokkah boeng reaction of a parental cultivar can be used to predict the overall pokkah boeng reaction of hybrid populations produced from that cultivar. Although highly-susceptible parents may give some resistant progenies, crosses between susceptible parents apparently produce a higher frequency of susceptible progenies than do crosses between resistant parents.

Breeding value estimates (Table 4), based on average disease reactions of F_1 populations produced from each parental cultivar, showed that five parents (CP 70-300, CP 61-37, CP 52-68, CP 66-346, and CP 68-1067) tended to produce resistant progenies. Three cultivars (CP 63-588, CP 57-526, and CP 62-374) produced progenies with intermediate reaction, and two cultivars (CP 57-614 and NCO 310) produced relatively high frequencies of

TABLE 3. Pokkah boeng ranks[a] of five sugarcane clones used as males and five used as females, evaluated in clonal, self, and F_1 populations

Clones compared	Clonal	Selfs	Mean of 5 crosses	F_1 populations with female: CP 68-1067	CP 52-68	CP 62-374	NCO-310	CP 61-37
Males:								
CP 70-300	1	1	1	2	1	1	2	2
CP 63-588	2	3	3	1	4	4	1	4
CP 66-346	3	2	2	4	3	2	3	1
CP 57-526	4	4	4	3	5	3	5	3
CP 57-614	5	5	5	5	2	5	4	5
				F_1 populations with male:				
Females:				CP 57-526	CP 63-588	CP 66-346	CP 70-300	CP 52-614
CP 52-68	1		2	4	2	2.5	1	1
CP 61-37	2		1	1	3	1	3	2
CP 68-1067	3		3	2	1	4	4	3
CP 62-374	4		4	3	5	2.5	2	5
NCO 310	5		5	5	4	5	5	4

[a] 1 = least disease: 5 = most.

TABLE 4. Breeding value[a] of 10 sugarcane clones for pokkah boeng reaction

Clone	Mean score of F_1 progeny[b]	Breeding value[a]
CP 70-300	11.42	−12.44
CP 61-37	12.39	−10.50
CP 52-68	12.87	− 9.54
CP 66-346	13.07	− 9.14
CP 68-1067	14.11	− 7.06
CP 63-588	17.62	− 0.04
CP 57-526	20.26	+ 5.24
CP 62-374	20.94	+ 6.60
CP 57-614	25.81	+16.34
NCO 310	27.86	+20.44

[a]Breeding value = 2 (Mean score of all populations for which the given clone was a parent - mean score of all populations).

[b]Mean score = Percentage of plants in plot showing mild pokkah boeng symptoms + 2 (percentage of plants showing severe symptoms).

susceptible progenies.

Estimates of the heritability of pokkah boeng reaction were all high. Broad-sense estimates from analysis of variance of clonal plots showed that 88.4% of the variation among plots was due to genetic differences among plots. The corresponding heritability estimate for selfed populations was 89.9% and for F_1 populations, 61.5%.

The correlation between the pokkah boeng scores of F_1 populations and their female parents was 0.59, and that for F_1's and the male parents was 0.50. These values imply heritabilities near 100%. The narrow-sense heritability estimate obtained from F_1 − midparent correlation was 70%, with a 5% confidence interval of 41% to 83%.

Analysis of variance for 25 F_1 populations with six replications makes it possible to compare the relative importance of male parents, female parents, male-female interaction, and nongenetic factors in terms of the contribution that each makes toward the total observed variation among plots. The results were: $\sigma^2_{\text{females}} = 51.8\%$; $\sigma^2_{\text{males}} = 35.4\%$; $\sigma^2_{\text{male-female interaction}} = 2.3\%$; $\sigma^2_{\text{nongenetic}} = 10.5\%$. The small size of $\sigma^2_{\text{male-female interaction}}$ compared to $\sigma^2_{\text{females}}$ and σ^2_{males} indicates that, for pokkah boeng reaction in these crosses, specific combining ability is small compared to general combining ability.

The data obtained in this study clearly establish the genetic transmissibility of pokkah boeng susceptibility. Breeders who use susceptible clones in crosses should be prepared to discard a relatively large fraction of the seedlings because of pokkah boeng susceptibility.

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