

## **ESTIMATING THE FAMILY PERFORMANCE OF SUGARCANE CROSSES USING SMALL PROGENY TEST**

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### **ABSTRACT**

Improvement of sugarcane seedling populations by eliminating inferior progeny should increase the frequency of elite clones and increase the selection efficiency. The objective of this study was to evaluate the effectiveness of a progeny testing technique using a progeny performance test with a small number of seedlings per cross. Approximately seventy seedlings per cross from the seed germination tests of 1987, 1988, and 1989 cross series were transplanted to the field along with the regular seedling program. Selection rate and visual grade were assessed on each cross and forty seedlings were randomly selected for the measurement of stalk diameter, stalk number, stalk weight, and juice quality on each progeny. Selected Stage I clones were planted in Stage II tests for the measurement of juice quality. Multiple regression analyses were used to select the best predictive model for the progeny performance based on the selection rate. Results indicated that the frequency distribution of selection rates of all three cross series was markedly skewed toward higher performance in both small progeny tests and the regular seedling program. Stalk diameter was the best predictor of the selection rate within the regular seedling program. Information obtained from small progeny tests should help breeders select superior crosses to increase the incidence of elite clones for their regular seedling program.

### **INTRODUCTION**

The Canal Point sugarcane variety development program (Tai and Miller, 1989) annually evaluates approximately 100,000 seedlings. Improvement of sugarcane seedling populations by eliminating inferior progeny would increase the frequency of superior seedlings and increase selection efficiency. Selection in original seedlings is intended to obtain some superior varieties, and to improve the average value of the whole population (Hogarth, 1987). There are numerous difficulties during the early stages of selection including the large number of clones, performance differences to be expected from single stools, later from the necessarily small plots, and the subjective nature of selection at this stage (Arceneaux et al., 1986). Numerous experiments have been conducted to assess the effectiveness of selection for a particular character or set of characters, the correlations between such characters, and prediction of response to selection (Brown et al., 1968; Hogarth, 1971; Miller and James, 1975; Miller et al., 1978; Tai and Miller, 1989; Walker, 1965). Walker (1965) reported that Brix is a better selection criterion because of its high correlation between stages, and stalk number is also a reasonably good selection criterion, but cane weight

is not very reliable. Sugar content is poorly correlated at the two ages and no attempt is made to select for high sugar in these early ages. Tai et al. (1980) reported that stalk number, stalk weight, Brix, sucrose percent, and sugar per ton of cane were highly repeatable between selection stages (Stages II and III), but tons of cane per hectare, and tons of sugar per hectare, were not repeatable between these two selection stages.

In addition to selection for a single character, the selection index can be used by combining many important characters into a single measure (Hogarth, 1987). Miller et al. (1978) used stalk length, stalk diameter, stalk number, and Brix to construct a selection index for tonnes of sugar per hectare. Direct measurement of many important characters of sugarcane is time consuming and expensive. Sugarcane breeders have used grading systems (visual rating) to evaluate the potential commercial value of clones (Skinner, 1967). Grading is less accurate but less expensive than the selection index.

Several methods have been proposed for estimating the potential of sugarcane families to produce superior seedlings (elite genotypes), including factors for superior performance (FSP) by Arceneaux et al. (1986), the probability of exceeding a target value (PROB) (Milligan and Legendre, 1991), and a univariate cross prediction method (Chang and Milligan, 1992). The factors for superior performance (FSP) method is easy to use, but a FSP value can only be obtained after the original seedlings have been carried through all stages of selections. The univariate cross prediction method described by Chang and Milligan (1992) requires extensive data collection.

The selection percentage is a measure of the overall merit of the cross which represents all the aspects of desirability considered in these stages and the weight given to each component character by the selector (Walker, 1963). A high selection percentage indicates that the population had a high mean and/or variance for some or all desirable characters. Tai and Miller (1989) reported that selection rate between early stages of selection was highly correlated.

A progeny test with small number of individuals is routinely used to estimate the selection rate for the evaluation of proven crosses in sugarcane breeding programs in Australia (Hogarth, 1987). The progeny assessment trials also have been routinely used to identify the best families and select the superior clones from these families (Cox et al. 2000). Wu et al. (1978) studied the minimum sample size as the minimum number of individual sugarcane seedlings or stools necessary to estimate, with reasonable precision, mean and variance of a trial in a population and found forty individuals from a population to be the minimum sample size required to estimate the mean and variance for refractometer solids (Brix), stalk number, stalk diameter, or stalk length.

The objective of this study was to evaluate the effectiveness of using small numbers of seedlings per cross to estimate the progeny performance of families based on the selection rate.

## **MATERIALS AND METHODS**

Progeny tests were established in each May of 1988, 1989, and 1990 by planting 70 to 100 seedlings per cross from the regular seed germination tests for 1987 (33 entries), 1988 (44 entries), and 1989 (29 entries) cross series, respectively. Those seedlings were transplanted to the field in two rows

1.5 m apart with 0.3 m between seedlings within a row. A visual rating (R1) (poor = 1, fair = 3, and good = 5) was made on each cross in early December of the same year. Data on stalk diameter (D1) were collected from up to five stalks for each of those 40 seedlings picked at random in late December. Stalk diameter was measured near the mid-internode at 0.30 m above ground level and the number of millable stalks for each seedling was recorded. Stool weight (K1) was calculated by multiplying the stalk weight (W1) by the stalk number (N1). Data on stool weight were obtained from both the 1988 and the 1989 cross series. One stalk was cut from each of 40 seedling stools. The resulting 40-stalk bundle per cross was weighed and divided at random into two sub-samples, 20 stalks each, for juice analysis. The average Brix or sucrose from the two sub-samples was used for all statistical analyses.

Selection using the same criteria as the regular seedling program (Tai and Miller, 1989) was conducted in early January. Selection rate from the progeny test (SR1) (%) was computed as: (selected seedlings/number of seedlings of each progeny sample) X 100. Approximately 600 to 1,000 seedlings for each of those same crosses used in the progeny test were planted in the regular seedling program in the following year (CP 90, CP 91 and CP 92 clones selected from 1987, 1988, and 1989 cross series, respectively). Selection rates for the regular seedling stage (SR2) (%) were computed as: (selected seedlings/number of regular seedlings per cross) X 100. One stalk (approximately 1 m long) from each of those selected seedlings was cut in January each year and planted as Stage I in a single-row plot in 1.5 m between rows and 0.6 m apart between plots. Plant-cane selection of Stage I clones was conducted in September of each year. Selection rate for Stage I (SR3) (%) was computed as (selected Stage I clones/original seedlings per cross) X 100. Each selected Stage I clones was advanced to Stage II (Tai and Miller, 1989). An eight-stalk seed cane sample was cut from each selected clone in Stage I and used to establish a 2-row plot 4.6 m long and 1.5 m wide in Stage II in October each year. Juice quality data were based on the Stage II samples harvested the following October. Juice quality was not measured on selections made in Stage I, the average of juice quality measurements from Stage II clones in each cross was used for all statistical analyses.

Predicting the selection rate (%) for progeny sample (SR1), regular seedling (SR2), and Stage I (SR3) was made by regression analysis (SAS, 1988) using the progeny assessment data on stalk diameter, stalk weight, and visual rating. The multiple regression of dependent variables, selection rates (SR1, SR2, and SR3), on stalk diameter (D1), stalk weight (W1), stalk number (N1), stool weight (K1), and visual rating (R1) based on the progeny test for each cross series were analyzed. The GLM procedure (SAS, 1988) was used to select the best predictive models for SR1, SR2 or SR3.

## RESULTS AND DISCUSSION

The seedlings of the regular Seedling Stage generally had lower stalk weight and juice quality than the selected Stage I clones tested in Stage II (Table 1). Visual rating of three cross series ranged from 3.48 to 4.0 and their selection rates exceeded 20%. The results also indicate that the plant measurements for stalk characters and juice quality factors in Seedling Stage were smaller than those in Stage II. Those differences could be due to the plant development stage and the growth environment. The seedlings were developed from the true seed with a limited food supply while Stage II clones developed from buds with adequate food supply from the cane stalks. DeSousa-Vieira and Milligan (1999) showed that the plant

spacing greatly affects stalk number and its variances.

Progeny tests suggest that a visual rating (R1) was closely associated with stalk diameter (D1) ( $r = 0.43^{**}$  for 1987 cross series,  $r = 0.37^{**}$  for 1988 cross series, and  $r = 0.65^{**}$  for 1989 cross series), while R1 was not consistently associated with stalk weight (W1) ( $r = 0.83^{**}$  for 1987 cross series and  $r = 0.41^{**}$  1989 cross series were significant, but  $r = 0.24$  for 1988 cross series was not significant, Table 2). D1 and W1 were positively correlated. Both the selection rate for progeny sample (SR1) and the selection rate for the regular seedling (SR2) were closely correlated with either D1 or W1 in both the 1987 and 1989 cross series. Both selection rates, SR1 and SR2, were strongly affected by both D1 and W1 as shown in both the 1988 and 1989 cross series, while the selection rate for the Stage I clones (SR3) was affected by neither trait. In most crosses, R1 was not significantly correlated with SR1, SR2, or SR3. SR2 was positively associated with SR3 in three cross series.

Correlations of juice quality between the progeny tests and selected Stage I clones were inconsistent. The 1987 crosses gave significant correlations while 1988 and 1989 cross series were not significant (Table 3). The inconsistency could be due to both plant growth stages and field environment (DeSousa-Vieira and Milligan, 1999). The seedlings and Stage II were planted at a very different intra-row spacing. This may explain why the selection rate from Seedling Stage to Stage I was not well correlated to stalk weight. The stalk diameter varied considerably among individual seedlings within a cross. Also the composite stalk sample, which consisted of one stalk per seedling stool, would not have an equal amount of cane juice or cane stalk weight representing each stool. The measurement may not closely represent the juice quality of seedlings. Maturity, which also varied considerably among seedlings and between crosses, would affect the quality of cane juice. Correlations between traits shows they were changing rather than static and would be affected by cane growth and maturity (Dodonov et al. 1987; Tai et al. 1996). Family selection based on the mean of some traits may not be very effective in the early stages of selection. The selection rate between Seedling Stage and Stage I was significantly correlated in all three series of crosses as reported earlier by Tai and Miller (1989). The results suggest that family selection based on the selection rate should be effective. The larger the number of superior families included in the Seedling Stage, the higher percentage of superior individual clones will be potentially selected for the Stage I and the subsequent selection stages.

The multiple regressions for SR1, SR2, and SR3 are summarized in Table 4. The best regression models varied among the progeny test, Seedling Stage, and Stage I. Results indicate that the selection rate would be heavily dependent on stalk diameter D1 and  $(D1)^2$  in the Seedling Stage. Other predictor variables were not chosen for the model for SR2 in any of the three cross series. Both the 1987 and 1989 crosses had very similar regression models for SR2, but they differed from that of the 1988 crosses. The quadratic regression model suggests that seedlings with either very thin or very thick stalks would drastically reduce the selection rate (Fig. 1). Seedling populations with an average stalk diameter between 21 and 25 mm would produce the highest selection rate. Predictor variables, stalk diameter (D1) and stalk number (N1), were chosen for the model for SR3 in the 1988 cross series and  $(R1)(W1)$  was chosen for the model in the 1989 cross series, but no predictor variable was chosen for the model for SR3 in 1987 cross series. The difference in the prediction models for SR2 and SR3 could be due to many factors. Stalk size of Stage I clones is generally much larger than that of the Seedling Stage due to selection for larger stalk diameter

in the Seedling Stage (Tai and Miller, 1989). The selection criteria in Stages I and II emphasize other characters, such as stalk number, stalk shape, growth habit, solidness, plant height, etc, versus stalk diameter. Both stalk number (N1) and rating (R1) x stalk weight (W1) appeared to be more predictive of selection rate in Stage I than stalk diameter (D1) based on the progeny test. DeSousa-Vieira and Milligan (1999) pointed out that the predicted family gains for millable stalk number per plant, stalk length and stalk weight using widely spaced plants would be more accurate than using narrowly spaced plants.

A progeny test with a small number of seedlings per cross should eliminate some of the poor crosses before a large population of seedlings is planted for the selection program. Adjusted R-squares of some regression models were relatively small; therefore, the effectiveness of predicting the selection rate might be low. Further study is needed to improve the regression model to estimate the selection rate. Even though individual (mass) selection can be more effective in maintaining genetic diversity of the seedling population than family selection, individual selection may not be the most efficient way to manage a seedling program. The progeny test to assess the potential performance of seedling progeny should benefit the selection program by planting larger numbers of the best progenies in the regular seedling program.

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### REFERENCES

1. Arceneaux, G., J. F. Van Breemen, and J. O. Despradel. 1986. A new approach in sugar cane breeding: comparative study of progenies for incidence of superior seedlings. *Sugar Cane* 1986 (1):7-10.
2. Brown, A. H. D., J. Daniel, and B. D. H. Latter. 1968. Quantitative genetics of sugarcane. II. Correlation analysis of continuous characters in relation to hybrid sugarcane breeding. *Theor. Appl. Genet.* 38:1-10.
3. Chang, Y. S., and S. B. Milligan. 1992. Estimating the potential of sugarcane families to produce elite genotypes using univariate cross prediction methods. *Theor. Appl. Genet.* 84:662-671.
4. Cox, M.C., D. M. Hogarth, and G. R. Smith. 2000. Cane breeding and improvement. In D. M. Hogarth, and P. G. Allsopp (eds.). *Manual of Cane Growing*. Bureau of Sugar Experiment Stations, Brisbane, Queensland, Aust., pp. 91-108.
5. DeSousa-Vieira, O., and S. B. Milligan. 1999. Intra-row plant spacing and family x environment interaction effects on sugarcane family evaluation, *Crop Sci.* 39: 358-364.
6. Dodonov, G. P., D. A. Cherepanov, I. I. Raponovich, and O. S. Melik-Sarkisov. 1987. Variation and correlation of morphophysiological traits of sugarcane during ontogeny and their selection of seedlings. *Soviet Agricultural Biology: Part 1 :Plant Biology* 1987 (3):79-87. Allerton Press, New

York.

7. Hogarth, D. M., 1971. Quantitative inheritance studies. II. Correlation and predicted response to selection. *Aust. J. agric. Res.* 22:103-109.
8. Hogarth, D. M. 1987. Genetics of sugarcane. In D. J. Heinz (editor), *Sugarcane Improvement Through Breeding*. Elsevier, New York. Pp. 255-272.
9. Miller, J. D., N. I. James, and P. M. Lyrene. 1978. Selection indices in sugarcane. *Crop Sci.* 18:368-372.
10. Miller, J. D., and N. I. James. 1975. Selection in six crops of sugarcane. I. Repeatability of three characters. *Crop Sci.*15:23-25.
11. Milligan, S. B., and B. L. Legendre. 1991. Development of a practical method for sugarcane cross appraisal. *J. Am. Soc. Sugarcane Technol.* 11:59-68.
12. SAS Institute. 1988. *SAS/SAT User's Guide 6.03ed.* SAS Inst. Inc., Cary, NC.
13. Skinner, J. C. 1967. Grading varieties for selection. *Proc. ISSCT* 12:938-949.
14. Tai, P. Y. P., J. D. Miller, B. S. Gill, and V. Chew. 1980. Correlations among characters of sugarcane in two intermediate selection stages. *Proc. ISSCT* 16:1119-1126.
15. Tai, P. Y. P., and J. D. Miller. 1989. Family performance at early stages of selection and frequency of superior clones from crosses among Canal Point cultivars of sugarcane. *J. Am. Soc. Sugarcane Technol.* 9:62-70.
16. Tai, P. Y. P., G. Powell, R. Perdomo, and B. R. Eiland 1996. Changes in sucrose and fiber contents during sugarcane maturation. *Sugar Cane* 1996(6):19-23.
17. Walker, D. I. T. 1963. Family performance at early selection stages as a guide to the breeding programme. *Proc. ISSCT* 11:469-483.
18. Walker, D. I. T. 1965. Some correlations in sugarcane selection in Barbados. *Proc. ISSCT* 12:650-655.
19. Wu, K. K., D. J. Heinz, H. K. Meyer, and S. L. Ladd. 1978. Minimum sample size for estimating progeny mean and variance. *Crop Sci.*18:57-61.

**Table 1.** Means and standard errors of some morphological and juice quality characters of small progeny tests and their selected Stage I clones from same crosses tested at Stage II.

Population <sup>†</sup>	Stalk			Visual rating	SR	Brix	Sucrose	Purity
	Diameter	Weight	Number					
	(mm)	(kg)					----- % -----	
1987 Crosses	22.17 ±0.29	0.62 ±0.05	-	3.48 ±0.18	23.92 ±2.45	14.07 ±0.14	9.60 ±1.49	67.63 ±0.91
CP 90 Stage II	-	1.39 ±0.08	-	-	1.24 ±0.17	16.19 ±0.13	12.33 ±0.23	75.90 ±0.77
1988 Crosses	20.81 ±0.24	1.10 ±0.07	3.12 ±0.08	3.97 ±0.17	20.36 ±1.67	15.85 ±0.13	13.77 ±0.20	85.92 ±0.60
CP 91 Stage II	-	1.88 ±0.05	-	-	1.84 ±0.44	17.70 ±0.08	16.57 ±0.16	92.69 ±0.61
1989 Crosses	24.35 ±0.34	0.88 ±0.06	3.86 ±0.08	4.00 ±0.15	23.72 ±0.21	17.35 ±0.17	16.22 ±0.36	93.38 ±1.71
CP 92 Stage II	-	1.63 ±0.09	-	-	2.93 ±0.21	17.76 ±0.17	15.97 ±0.29	89.87 ±1.21

<sup>†</sup>1987 Cross includes 33 seedling samples, 1988 Cross 44 samples, and 1989 Cross 29 samples. Stage I clones were selected from the original seedlings of same crosses and juice quality and stalk weight were measured on Stage II samples.

**Table 2.** Correlation between morphological characters and selection rating at various stages of selection.

		Progeny test					Seedling	Stage I
		Stalk Weight	Stalk number	Stool weight	Visual rating	Selection rate	selection rate	selection rate
<u>1987 Cross Series: df = 31</u>								
Progeny:	Stalk weight (W1)	0.63**						
	Stalk number (N1)	-	-					
	Stool weight (K1)	-	-	-				
	Visual rating (R1)	0.43**	0.23	-	-			
	Selection rate (SR1)	0.51**	0.59**	-	-	0.32		
Seedling:	Selection rate (SR2)	0.55**	0.38*	-	-	0.31	0.38*	
Stage I:	Selection rate (SR3)	0.23	0.24	-	-	-0.09	0.29	0.72**
<u>1988 Cross Series: df = 42</u>								
Progeny:	Stalk weight (W1)	0.24						
	Stalk number (N1)	- 0.30*	- 0.12					
	Stool weight (K1)	0.01	0.78**	0.52**				
	Visual rating (R1)	0.37**	0.21	0.17	0.08			
	Selection rate (SR1)	0.44**	0.12	0.22	0.22	0.37		
Seedling:	Selection rate (SR2)	0.28	0.22	-0.12	0.13	0.13	0.15	
Stage I:	Selection rate (SR3)	0.10	- 0.05	0.17	0.06	0.14	0.06	0.29*
<u>1989 Cross Series: df = 27</u>								
Progeny:	Stalk weight (W1)	0.41*						
	Stalk number (N1)	0.06	0.09					
	Stool weight (K1)	0.74**	0.90**	0.52**				
	Visual rating (R1)	0.65**	0.48**	0.45**	0.56**			
	Selection rate (SR1)	0.78**	0.71**	0.36*	0.51**	0.24		
Seedling:	Selection rate (SR2)	0.49**	0.42*	-0.19	0.26	0.44**	0.43*	
Stage I:	Selection rate (SR3)	0.37	0.36	-0.04	0.28	0.36	0.24	0.63*

\*, \*\*, Significant at P = 0.05 and 0.01, respectively.

**Table 3.** Correlation coefficients of juice quality characters between small progeny test and selected Stage I clones (CP 90 series from 1987 cross series, CP 91 series from 1988 cross series, and CP 92 series from 1989 cross series) tested in Stage II.

Correlation between <sup>†</sup>	Brix	Sucrose	Purity
1987 Crosses and selected CP 90 clones	0.40*	0.35*	0.36*
1988 Crosses and selected CP 91 clones	0.12	0.15	0.23
1989 Crosses and selected CP 92 clones	0.20	0.24	0.18

\* Significant at P = 0.05.

<sup>†</sup> Data on Brix, sucrose, and purity were based on samples collected from Stage II test.

**Table 4.** Regression models for selection rate of small progeny test (SR1), regular Seedling Stage (SR2), and Stage I (SR3) for each of the three cross series.

Regression equation <sup>†</sup>	R <sup>2</sup>
<u>1987 Cross Series:</u>	
SR1 = -10.710 + 1.164(D1)(W1)	0.46
SR2 = -305.462 + 28.854(D1) - 0.622(D1) <sup>2</sup>	0.59
<u>1988 Cross Series:</u>	
SR1 = -63.196 + 2.577(D1) + 0.233(D1)(N1)+ 0.531(R1)(N1)	0.58
SR2 = -0.285 + 0.027(D1) <sup>2</sup>	0.47
SR3 = 0.047 + 0.035(D1)(N1)	0.35
<u>1989 Cross Series:</u>	
SR1 = 526.900 - 25.126(D1) - 0.626(K1) <sup>2</sup> + 11.855(D1)(K1)-28.239(W1)(N1)	0.38
SR2 = -435.283 + 39.631(D1) - 0.859(D1) <sup>2</sup>	0.59
SR3 = 0.387 + 0.161(R1)(W1)	0.53

<sup>†</sup>The models were picked using the stepwise regression procedure. Data on D1 = diameter (mm), K1 = stool weight (kg), N1 = stalk number per seedling, W1 = stalk weight (kg), and R1= visual rating used for constructing regression models were based on the progeny