

REPEATABILITY WITHIN AND BETWEEN SELECTION STAGES IN A SUGARCANE BREEDING PROGRAM

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ABSTRACT

Aiming to obtain repeatability estimates ($r_{p(x)}$) to help in the identification of superior clones, six full-sib sugarcane families were evaluated in the first three of six clonal selection stages. The traits evaluated were: stalk length and diameter, stalk weight and number and Brix % cane juice. Results showed that, for stalk length and Brix, $r_{p(x)}$ estimates weren't significantly different between stages I and III and between II and III. For stalk diameter, stalk number and weight of stalks, there was a clear difference of $r_{p(x)}$ values between stages I and III and between II and III. These results indicate that, for phenotypic selection in stage I, priority should be given to Brix % cane juice and to stalk length in the first place, whereas from stage II forward, additional emphasis should be given to stalk diameter, number of stalks and weight of stalks. When the same selection stage is considered, repeatability estimates for each trait were also similar from plant to first ratoon, which indicates that selection for ratooning ability is not effective in the first two selection stages.

Keywords: sugarcane, repeatability, early selection

INTRODUCTION

New sugarcane cultivars are obtained through the selection of vegetatively propagated genotypes obtained from true seed, which is derived from the hybridization of superior parents. Selection is applied in all breeding stages: the choice of parents, cross combinations and the plant population originating from the crosses made (Skinner et al., 1987). Individual seedling selection during the initial stage is of low efficiency given the low broad sense heritability for the majority of traits (Skinner, 1982). It has been common practice in breeding programs to obtain phenotypic estimates for the traits under selection during the initial breeding stages. (Dudley and Moll, 1969; Skinner et al., 1987).

Repeatability estimates are utilized to measure the association of the same trait between different initial selection stages and crop cycles (plant cane and ratoons). Knowing these estimates helps to set up selection criteria for visual evaluation, which increases selection efficiency and reduces the risk of losing superior genotypes.

Studies with estimates of repeatability have been reported by Mariotti (1973) in Argentina, Miller and James (1975) and Milligan et al. (1996) in USA, Nageswara and Ethirajan

(1985) in India, Rodrigues (1986) in Colombia, Randoyal (1999) in Mauritius, and Bakshi Ram and Chaudhary (2000) in the West Indies, among others. Great variation in repeatability is observed among these studies, which indicates not only the influence of the environment on selection, but also a strong interaction between genotypes x environments and between genotypes x selection criteria.

The purpose of this work was to determine the estimates of repeatability for the more important traits in sugarcane, during the initial stages of selection and under the conditions of the breeding program in Braz

MATERIALS AND METHODS

The population utilized in this work was represented by the progenies of six bi-parental crosses (full-sibs), obtained at random from the Copersucar Breeding program, involving 12 different parents from the germplasm bank at Camamu, Bahia, Brazil. Seedlings obtained from each of the six crosses were planted in three experiments, one each year, in order to represent the first three selection stages of a total of six in the COPERSUCAR selection program. All experiments were planted in a randomized block design, with four replicates, and k genotypes (seedling or clone) within plots according to Steel and Torrie (1980), with k equal to 70 seedlings in experiment 1, 20 in experiment 2, and 10 in experiment 3. Sub-plot size varied from one stool spaced 0.5 m in the row in experiment 1, to one furrow two meters long in experiment 2, and then to two furrows six meters long in experiment 3. In all three experiments, rows were 1.4 m apart and the subplot sizes were the same as those used in the first three stages of selection in the Copersucar breeding program.

Twelve months after planting in the plant-cane stage, and 12 months after harvesting of the plant cane for the first-ratoon stage, we measured the following traits in the whole plot of each individual plant (sub-plot): stalk height (cm), stalk diameter (1 to 9 grade obtained with a cm-scaled rule, with 1 being the thickest diameter and 9, the thinnest one), stalk number, weight of stalks, and Brix % juice.

The repeatability estimates ($r_{p(x)}$) were obtained between crops and between selection stages. According to Falconer and Mackay (1996), $r_{p(x)}$ determines the upper boundary of the broad-sense heritability (h^2_a), and was estimated using the following expression:

$$r_{P(x)} = \frac{V_G + V_{EP}}{V_P}$$

where $r_{P(x)}$ represents the repeatability of trait x , V_G represents the genetic variance, V_{EP} is the permanent environmental variance and V_P is the phenotypic variance.

If V_{EP} is zero, $r_{P(x)} = h^2_a$. The permanent environmental variance occurs when data is collected and replicated over time in the same experiment, as is normal in sugarcane crops harvested over several ratoons. In vegetatively propagated crops like sugarcane, there is also the possibility of transmission of non-genetic effects (V_{EP}) with propagation. These effects

would appear in the next stage among the clones (Skinner, 1962). In this situation, repeatability among stages of selection has been used in sugarcane breeding.

The estimates of repeatability in each of the experiments, from the analysis of variance (Steel and Torrie, 1980), considered that seedlings or clones gave rise to two data sets (plant and ratoon stages) and was calculated as follows:

$$r_{P(x)} = \frac{\hat{S}_p}{\hat{S}_p^2 + \hat{S}^2}$$

where \hat{S}_p^2 is the estimate of the variance among seedlings or clones and contains the genetic variance among them plus the variance due to permanent environmental effects expressed in the two crop cycles (plant and ratoon). The term \hat{S}^2 measures the environmental variance, at the sub-plot level, due to interaction between seedlings or clones with the crop cycles.

Estimates of repeatability between the experiments 1 to 3 (stage I to III) were obtained through covariance analysis (Steel and Torrie, 1980), as it involved data from different experiments, as opposed to the case with crop cycles. Thus, these repeatabilities correspond to the phenotypic correlation of trait (x) on a given stage and this same trait (x'), in other selection stages and cycles and were estimated as follows:

$$\bar{r}_{P(x)} = \bar{r}_{P(x')} = \left(\frac{C\bar{\hat{v}}_{P(xx')}}{\sqrt{\bar{\hat{S}}^2_{P(x)} \bar{\hat{S}}^2_{P(x')}}} \right)$$

where $C\bar{\hat{v}}_{P(xx')}$ is the phenotypic covariance of trait x between experiments(stages), $\bar{\hat{S}}^2_{P(x)}$ is the mean phenotypic variance of trait x and $\bar{\hat{S}}^2_{P(x')}$ is the mean phenotypic variance of trait x'.

These analyses were first calculated for each cross and then after pooling for all crosses. For pooled data, a test for homogeneity among the estimates of repeatability between crosses was made and a χ^2 test was used to accept or reject it (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Estimates of repeatability in sugarcane are presented in Tables 1 to 5. Individual estimates for each cross are not presented separately since the differences for this group of crosses were not significant ($p > 0.05$) based on χ^2 test for homogeneity. Table 1 shows that the highest values for repeatability of stalk length were observed between stage III-plant and stage I-ratoon and also between stage II-ratoon and stage I-ratoon. These estimates are similar to those presented by Mariotti (1973) in Argentina, who found $r_{p(x)} = 0.36$ for mean stalk length between stages I and II on first ratoon crop. On the other hand, Bakshi Ram and Chaudhary (2000) found estimates that varied from 0.15 to 0.21 between stage I and II plant cane for three open crosses.

Under these same conditions, Rodrigues (1986) observed estimates between 0.5 and 0.6 for $r_{p(x)}$ in the plant crop, while Randoyal (1999), using family means, found values of 0.59 and 0.60 for repeatability among plant cane and ratoon in stage I.

Table 1. Repeatability estimates for stalk length.

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.39**	0.37*	0.42**	0.43**
	Ratoon		0.32**	0.54**	0.56**
Stage II	Plant			0.38**	0.49**
	Ratoon				0.52**

** significant at the 0.01 level

The absence of significant differences of repeatability between plant-cane and first-ratoon crops in stages I and II indicates that selecting for stalk length could be done in the plant cane crop, which results in a higher selection gain per unit of time, given that the genotypes under selection will reach stage III two years after planting stage I. However, selecting for stalk length must be liberal, given that the correlation values between stages I and III and between stages II and III did not exceed 0.5.

Table 2 presents repeatability values observed for stalk diameter. Repeatabilities were slightly higher than those obtained for stalk length, with no difference between plant and first-ratoon crops. The repeatability observed between stages I and III were inferior to those observed between stages II and III, indicating that selection for this trait on stage I has low efficiency, particularly on ratoon crops. Our recommendation is that selection for stalk diameter on stage I should be very liberal, and more intense on stage II, where repeatability is higher. The repeatability values obtained in this study are close to those obtained by Rodrigues (1986) but inferior to those reported by Bakshi Ram and Chaudhary (2000), who found estimates between 0.84 and 0.90. We recommend that selection for stalk diameter should be made on plant cane in stages I and II.

Table 2. Repeatability estimates for stalk diameter

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.52**	0.58**	0.45**	0.45**
	Ratoon		0.47**	0.42**	0.37**
Stage II	Plant			0.53**	0.62**
	Ratoon				0.55**

** significant at the 0.01 level

For stalk number (Table 3), the highest repeatability occurred in stage II between plant cane and first ratoon, with $r_{p(x)} = 0.69$. Repeatabilities between stage I and II were low, close to those obtained for stalk length and inferior to those obtained for stalk diameter. However, between stages I and III and between stages II and III, repeatability values were higher than those obtained for stalk length and close to those obtained for stalk diameter. In this case our results are different from those of Rodrigues (1986) and Bakshi Ram and Chaudhary (2000), but similar to those of Miller and James (1975), who found repeatability values between stages I, II and III similar to those for stalk diameter (0.5).

Table 3. Repeatability estimates for stalk number

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.63**	0.34**	0.36**	0.41**
	Ratoon		0.39**	0.44**	0.46**
Stage II	Plant			0.69**	0.60**
	Ratoon				0.55**

** significant at the 0.01 level

Table 4 shows repeatabilities for Brix % cane juice. Here the $r_{p(x)}$ values obtained among all stages and crosses were uniform and high, with values greater than 0.60 in most cases, which indicates that Brix % cane juice is the character with highest repeatability in the initial stages of selection. The plant-cane crop had the most uniform results when compared to those obtained for the ratoon crop, with the highest values occurring between stages I and II, in plant cane. These values are higher than those reported in the literature (Mariotti, 1973; Miller and James, 1975; Nageswara and Ethirajan, 1985; Rodrigues, 1986; Bakshi Ram and Chaudhary, 2000).

Table 4. Repeatability estimates for Brix % cane juice.

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.45**	0.78**	0.72**	0.67**
	Ratoon		0.71**	0.68**	0.62**
Stage II	Plant			0.59**	0.70**
	Ratoon				0.67**

** significant at the 0.01 level

As a quantitative trait, resulting from other yield components (stalk length, stalk diameter and number of stalks), the weight of stalks had low repeatability values (Table 5). These values were small between stages I and II and between stages I and III, both for plant and ratoon crops.

Repeatability values between stages II and III were higher, however, indicating that weight of stalks in stage I should not be used as a direct selection criterion. Its components – stalk length, stalk diameter and number of stalks – should instead be preferred for selection in this stage.

Table 5. Repeatability estimates for stalk weight.

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.48**	0.35**	0.36**	0.29**
	Ratoon		0.33**	0.42**	0.30**
Stage II	Plant			0.60**	0.57**
	Ratoon				0.53**

** significant at the 0.01 level

Based on the results obtained in stage III (which is the stage with the largest plot, lowest genotype x environment interaction and lowest competition between plots compared to previous stages) the following observations were made: (a) for stalk length and Brix, $r_{p(x)}$ values weren't significantly different between stages I and III and between stages II and III; (b) for stalk diameter, stalk number and weight of stalks, there was a clear difference of $r_{p(x)}$ values between stages I and III and between stages II and III. These results indicate that, for phenotypic selection in stage I, priority should be given to Brix % cane juice and to stalk length, whereas from stage II forward, additional emphasis should be given to stalk diameter, number of stalks and weight of stalks.

CONCLUSIONS

Brix % cane juice presented high repeatability values between stages I and III and also between plant-cane and first-ratoon crops. Particularly for this trait, individual selection can be intensified in stage I.

Stalk length showed low repeatability between stages I and II and intermediate repeatability between stages I and III and stages II and III, in both plant and ratoon crops. Given the similar values for $r_{p(x)}$ between stages I and III and stages II and III, we reached the conclusion that the same criterion utilized for selection on stage I can be applied on stage II.

The traits stalk diameter and number of stalks showed moderate repeatability among all stages and crops studied, with $r_{p(x)}$ values between stages II and III slightly higher than those between stages I and III, for both crops. In this scenario, selection for these traits in stage I should be less intense than in stage II, and it can be applied on plant cane.

Weight of stalks had low repeatability in stage I, and intermediate repeatability in stage II. Repeatability values were lower than those found for the number of stalks, stalk length and

stalk diameter in this study. As a recommendation, individual selection based on weight of stalks should be avoided in stage I, being applied only from stage II forward.

Regarding the plant and ratoon crop cycles, the values found for repeatability indicated that the individual selection could be applied on plant cane for both stages I and II, since the $r_{p(x)}$ values obtained were similar for plant cane and ratoon cane.

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