Heritability estimates for quality and ear traits in sweet corn

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ABSTRACT

The development of cultivars with reduced pericarp thickness, high sugar content and husks covering ear tip will improve the market for Brazilian sweet corn and may open a new market for export. The knowledge of parent-offspring relationship helps to choose a breeding method, to decide selection intensity, and to predict genetic gains for the traits under selection. The objective of this work was to estimate heritability for pericarp thickness, soluble solids content and percent of ear tip in three open-pollinated sweet corn populations - BR400, BR401, and BR402 - using half and full-sib families. Genetic variability was detected for all traits in the evaluated populations. The estimated heritability for pericarp thickness was larger than those estimated for soluble solids content, and percent of ear tip for all populations in this study. As a consequence, the expected genetic gains will be larger for pericarp thickness than for the other traits evaluated in this work.

KEY WORDS: Genetic parameters, quality traits, maize.

INTRODUCTION

Sweet corn has similar requirements for agronomic traits when compared to field corn. However, traits related to grain and ear quality are specific demands. A thin pericarp, high soluble solids content, mainly composed of glycose, fructose, and sucrose, and good husk covering are important in sweet corn cultivars (Tracy, 1997). The first two traits limit commercialization in the international market, mainly when extra sugar is added during sweet corn processing (Tracy, 1997). In the same way, complete husk covering provides resistance to earworm attack (Lynch et al., 1999; Gardner et al., 2000).

In order to develop sweet corn cultivars with thin pericarp, high soluble solids content, and complete husk covering the existence of genetic variability for these traits is fundamental in segregating populations. Therefore, knowledge about the relationship between parents and progeny is necessary, which is estimated by heritability (Falconer, 1960). A correct estimate of this parameter guides the choice of breeding method and selection intensity to be used for each trait; as well allowing an estimation of the genetic gains to be obtained (Carvalho et al., 1981).

Heritability has been estimated for several types of family in sweet corn, including half-sib, full-sib, and selfed S_1 or S_2 families (Abedon and Tracy, 1998). The values for pericarp thickness found in the literature have been medium or large, ranging from 0.55 (Ito and Brewbaker, 1991) to 0.80 (Helm and Zuber, 1972). Genetic gain obtained by Ito and Brewbaker (1981) was 9.2% per cycle when selecting for reduction of this trait in the population *Hawaiian Super-sweet #9*. On the other hand, for soluble solids content, heritability estimates were not found in the literature. However, Wong et al. (1994) pointed out that genotype x environment interaction effect (GxE) was more important than genotype effect in the determination of this trait. Estimation for husk covering indicated heritability as large as 0.60, where several authors suggested a strong environmental influence on its expression (Hansen et al., 1977; Brewbaker and Kim, 1979; Rubino and Davis, 1990).

This paper aimed at estimating heritability and genetic gains for pericarp thickness, soluble solids content, and husk covering in three Brazilian sweet corn populations.

MATERIAL AND METHODS

Genotypes were evaluated in the Estação Experimental Agronômica of the Universidade Federal do Rio Grande do Sul (EEA/UFRGS), Brazil. The open pollinated populations used in this study were BR400, based on the gene *brittle 1* (*bt1*), BR401 and BR402, based on *sugary 1* (*su1*), all developed by EMBRAPA. The populations BR400 and BR401 were developed from Hawaiian introduced germplasm, supersweet and sweet series, respectively. BR402 traces back to Cuban Sweet germplasm (Reifschneider et al., 1984). Families were formed by manual pollination in 1998/1999 within each population. Full sib families were developed for BR400 and BR401, and half sib families for BR402. In 1999/2000, Experiment I, 47 families from BR400, 23 from BR401, and 36 from BR402 were evaluated, whereas in 2000/2001, Experiment II, 30 half-sib families from each population were assessed. These families were obtained in the winter of 2000 and no selection was accomplished. This way, two independent heritability values were estimated.

A randomized block design was used in both years, with five replications in 1999/2000 and three in 2000/2001. Experimental unit was a 5 m row spaced by 0.7 m among rows. Final planting density was, approximately, 42,000 plants/ha. Fertilization consisted of 40 kg/ha of nitrogen (N), 80 kg/ha of P_2O_5 and 40 kg/ha of K_2O at sowing. Additional nitrogen was delivered in two doses, stages V 3-4 and V 6-7 (Ritchie et al., 1992), totaling 90 kg/ha of N. Other cultural practices and irrigation were carried out as necessary.

The evaluated traits were pericarp thickness (micra), total soluble solids content (brix), and percentage of ear tip (%). In order to control variations during pollination time, all ears were protected with plastic bags as they emerged from the sheath. When approximately 85% of the ears in each experimental unit showed receptive stigma they were uncovered and allowed to pollinate. Kernels of adjacent rows in the medium third of the ears were picked 25 days after pollination and frozen at -18ºC. The technique used to determine pericarp thickness consisted of obtaining images of two kernels per experimental unit, removing their pericarp on the opposite side of the embryo with a razor blade and taking new images. The average difference in the thickness between the images was considered the pericarp thickness. The total soluble solids content, which is composed mainly of simple sugars and sucrose, was evaluated in five frozen kernels per experimental unit. Percentage of ear tip was evaluated considering the percentage of ears showing the tip in relation to the total number of ears in the experimental unit.

The data for ear tip was transformed by arcsin of the square root in order to obtain normal distribution. The results were submitted to analysis of variance, using a random effects model. Estimates of variance components and genetic gain were taken according to Paterniani and Miranda Filho (1980). Heritability was estimated through $h^2=\sigma^2_{Gf}/\sigma^2_{Pf}$, where h^2=heritability; σ^2_{Gf}=genotypic variance between families and σ^2_{Pf}=phenotypic variance between families. Genetic gains were calculated with $GS=k\sigma^2_{Gf}/(\sigma^2_{Pf})^{-1/2}$, where GS: genetic gain; k: selection intensity; σ^2_{Gf}: genotypic variance between families and σ^2_{Pf}: phenotypic variance among families.

RESULTS AND DISCUSSION

Analysis of variance detected significant differences among families in both years of evaluation for pericarp thickness. On the other hand, for soluble solids content and percentage of ear tip the differences were significant only in 2000/2001 (Table 1).

Population BR400 presented a thicker pericarp for family average and BR402 a thinner one in both evaluated years (Table 2). BR401 was not different from BR400 for pericarp thickness. The observed averages for this trait were larger than those obtained in open pollinated populations of sweet corn by Ito and Brewbaker (1991), indicating the need of further selection cycles to reduce pericarp thickness in the studied populations. Using a selection intensity of 20%, 14, 9, and 19 families would be selected in 1999/2000 for BR400, BR401 and BR402, respectively (Table 2). In the year of 2000/2001, the number of selected families was smaller in populations BR400 and BR402 and larger in BR401 (Table 2). This behavior suggests a different environmental influence in the populations depending on the year, altering family performance within populations. The best families for pericarp thickness in BR402, the population with thinner pericarp, presented thickness of 72-78 microns, which was approximately 50% above the ideal according to Zan and Brewbaker (1999).

In the year of 1999/2000, the largest soluble solids content, on average, was obtained in BR400 families and the smallest in BR401 (Table 2). On the other hand, all evaluated populations presented similar behavior for this trait in 2000/2001. The large value for soluble solids content in the population BR400 in 1999/2000 occurred, probably, because it contains the gene *brittle 1*, super-sweet type. This fact may lead to a superior sugar accumulation when compared to the other evaluated populations, both based on the gene *sugary 1* (Paiva et al., 1992). The differences among the populations BR401 and BR402 were probably due to the largest homeostasy of the second one, which presented less sensibility to environmental stresses in 1999/2000. These environmental stresses were caused mainly by low precipitation associated to high temperatures, which decreased irrigation efficiency. The number of superior families was similar among the populations in both years (Table 2). The best family performance for soluble solids content in the year of 2000/2001 was 15.8, 15.0, and 14.8 brix for BR402, BR401, and BR400, respectively. The values found in this work were lower than those reported by Wong et al. (1994); however, these authors evaluated hybrids containing the gene *shrunken 2*, which have higher accumulation of simple sugars, especially sucrose.

The average percentage of ear tip in the populations was 21.5% and extreme values were observed in 2000/2001, with 6.0% and 37.0% in BR402 and BR400, respectively. The differences among populations in the average of the families were significant, and population BR402 presented the smaller values for this trait (Table 2). The number of selected families was similar in the populations BR400 and BR402, in both years; however, in the

Table 1. Analysis of variance for pericarp thickness (micra), soluble solids content (brix), and percentage of ear tip (%) evaluated in 1999/2000 and 2000/2001 in three sweet corn populations. Porto Alegre, RS, Brazil.

			Mean square					
	Df		Pericarp thickness		Soluble solids		Percentage of ear tip	
Source	99/00	00/01	99/00	00/01	99/00	00/01	99/00	00/01
				BR400				
Rep	4	2	1225.46	26.29	3.68	5.03	0.0204	0.0319
Family	45	29	1844.61 1/	986.80 2/	3.44	7.47 2/	0.0176	0.0675 2/
Error	117	58	1091.33	72.75	2.58	2.38	0.0182	0.0320
CV (%)			24.00	9.68	16.23	12.12	23.04	24.13
				BR401				
Rep	4	2	9624.63 2/	88.45	1.58	3.77	0.0414 1/	0.2128
Family	22	29	2580.76 2/	866.97 2/	2.74	11.92 2/	0.0137	0.0523 2/
Error	53	58	1055.37	36.00	2.11	3.48	0.0131	0.0213
CV (%)			24.87	4.54	34.93	13.97	22.28	22.87
				BR402				
Rep	4	2	37.50 1/	165.05 2/	9.42 1/	3.09	0.0175 1/	0.0047
Family	35	29	1160.80 2/	611.47 2/	4.05	17.86 2/	0.0062	0.0340 2/
Error	70	58	12.71	29.79	2.74	4.39	0.0074	0.0093
CV (%)			4.08	4.84	23.11	14.69	33.75	29.91

1/ Significant by F test at 5% probability; 2/ Significant by F test at 1% probability.

Table 2. Mean and number of selected families (NSF) considering a selection intensity of 20% to reduce pericarp thickness (micra), to increase soluble solids content (brix), and to decrease the percentage of ear tip. Traits were evaluated in experiments in three sweet corn populations. Porto Alegre, RS, Brazil.

	Pericarp thickness		Soluble solids		Percentage of ear tip	
Population	Mean	NSF	Mean	NSF	Mean	NSF
			Experiment I			
BR400	138 a 1/	14	9.7 a 1/	10	33.0 a 1/	16
BR401	131 a	9	4.8 c	7	25.0 b	7
BR402	87 b	19	7.0 b	9	10.0 c	10
			Experiment II			
BR400	136 a	10	12.7 a	8	37.0 a	14
BR401	132 a	14	13.3 a	10	18.0 b	15
BR402	105 b	6	14.3 a	8	6.0 c	12

1/ Means followed by the same letter do not differ significantly by Tukey at 5% probability.

population BR401 seven families would be selected in 1999/2000 and 15 in 2000/2001. The best families were observed in population BR402 and the values oscillated between 0.3 and 1.7% of plants showing the ear tip. These results agreed with those obtained by Brewbaker and Kim (1979), where the authors found significant variation for the trait among field corn hybrids evaluated in different years.

Estimated phenotypic variance for pericarp thickness in the populations BR400 and BR402 was similar in both years; however, in BR401 the estimated value was larger in the first year (Table 3). For soluble solids content the phenotypic variance estimates were lower in 1999/2000 and for percentage of ear tip the values were larger in 1999/2000 (Table 3). The comparison of additive variance estimates showed larger values in 2000/2001 for all traits, except for pericarp thickness in BR401 and BR402 (Table 3). The estimates for pericarp thickness were larger than those obtained by Ito and Brewbaker (1991) in sweet and field corn inbreds.

Heritability values in 2000/2001 and in the population BR402 in 1999/2000 were in the narrow sense, because the evaluated families were half-sibs, with ¼ of additive variance. For BR400 and BR401 in the first year, full-sib families were evaluated, where ¼ of dominance was present, being heritability estimates in the broad sense. For pericarp thickness, the estimates ranged from 0.41 to 0.99 in the populations BR401 and BR402, respectively, in the year of 1999/2000 (Table 4). In the year of 2000/2001 this range was narrow, 0.82 in BR400 to 0.95 in BR401. In this work, the results obtained for this trait were larger than those observed in field and sweet corn (Helm and Zuber, 1972; Ho et al., 1975; Ito and Brewbaker, 1991). A smaller environmental influence on the families was observed for soluble solids content in 2000/2001, with larger heritability estimates (Table 4). The variation between years, observed in this study, are in agreement with the data from Wong et al. (1994) who found that at the most 24% of the variation in soluble solids content was of genetic origin. For percentage of ear tip, heritability estimates varied from low values in the year of 1999/2000 to medium to high in 2000/2001 (Table 4). These values in 1999/2000 were lower than the estimates presented by Brewbaker and Kim (1979).

The largest genetic gains estimated for pericarp thickness and soluble solids content were observed in populations BR401 and BR402, respectively; while for percentage of ear tip all populations showed similar values (Table 5). However, as differences existed among the averages of the populations, the percentage of genetic gain was estimated. In general, population BR402 presented larger gains for all evaluated traits (Table 5). The gains estimated in the present work were larger than those presented by Ito and Brewbaker (1981). However, due to the initial deficiencies of the populations, it is necessary additional selection cycles to reach values for pericarp thickness considered as superior quality by Zan and Brewbaker (1999). For the trait soluble solids content, it is also necessary four to five selection cycles to reach 20 degrees brix, which was pointed out by Wann et al. (1971) as ideal for industry processing.

The largest deficiency for percentage of ear tip was observed in the populations BR400 and BR401. A large number of selection cycles is needed to improve the trait. However, the existence of genetic variability indicates the possibility of constant genetic progress through selection.

The behavior of the traits pericarp thickness, soluble solids content, and percentage of ear tip suggests that several genes are involved in their inheritance. This implies that phenotypic selection may be efficient in the beginning of the selection process, when there is

Table 3. Phenotypic (s^2_P) and additive (s^2_A) variances for pericarp thickness, soluble solids content, and percentage of ear tip observed in two experiments in three sweet corn populations. Porto Alegre, RS, Brazil.

	Pericarp thickness		Soluble solids		Percentage of ear tip[1/]	
Population	Phenotypic	Additive	Phenotypic	Additive	Phenotypic	Additive
			Experiment I			
BR400	368.92	150.66	0.69	0.17	0.0352	0.0082
BR401	516.15	305.08	0.55	0.26	0.0274	0.0046
BR402	232.16	229.62	0.81	0.26	0.0184	0.0012
			Experiment II			
BR400	328.93	271.35	2.49	1.70	0.0225	0.0118
BR401	288.99	276.99	3.97	2.81	0.0174	0.0103
BR402	203.82	193.89	5.95	4.49	0.0113	0.0082

[1/] Values were estimated using the transformed variable.

Table 4. Heritability for pericarp thickness, soluble solids content, and percentage of ear tip estimated in two experiments in three sweet corn populations. Porto Alegre. RS, Brazil.

	Pericarp thickness		**Soluble solids**		**Percentage of ear tip**	
Population	Experiment I	Experiment II	Experiment I	Experiment II	Experiment I	Experiment
BR400	0.41	0.82	0.25	0.68	0.23	0.53
BR401	0.59	0.96	0.31	0.71	0.17	0.59
BR402	0.99	0.95	0.32	0.75	0.15	0.73

Table 5. Genetic gain[1/], per cycle, for pericarp thickness reduction (micra), soluble solids content increase (brix), and percentage of ear tip reduction (%) based on Experiment II evaluation in three sweet corn populations. Porto Alegre, RS, Brazil.

Population	Pericarp thickness		Soluble solids		Percentage of ear tip	
BR400	20.0[2/]	14.7[3/]	1.5[2/]	11.7[3/]	1.2[2/]	3.2[3/]
BR401	22.0	16.7	1.9	14.6	1.2	6.4
BR402	18.0	16.8	2.5	17.8	1.1	19.0

[1/] Estimation of genetic gains considering a selection intensity of 20% (k = 1.38); [2/] Genetic gains presented in measured units; [3/] (Genetic gain / trait average) x 100.

plenty genetic variability. After some selection cycles, it may be necessary to use a progeny test in order to obtain genetic progress in the evaluated populations.

CONCLUSIONS

There is genetic variability for pericarp thickness, soluble solids content, and percentage of ear tip in the populations BR400, BR401, and BR402, suggesting that plant selection in these populations is feasible.

Population BR400 has thicker pericarp and largest soluble solids content.

Population BR402 has the best ear tip coverage.

Heritability estimates were high for pericarp thickness and medium for soluble solids content and percentage of ear tip; which suggest larger genetic gains through selection for the first trait.

RESUMO

Estimativas de herdabilidade para caracteres da espiga e qualidade do grão em milho doce

O desenvolvimento de cultivares com reduzida espessura de pericarpo, elevado teor de sólidos solúveis e bom empalhamento de espiga poderá incrementar o mercado de milho doce brasileiro, podendo abrir novos mercados para exportação. O entendimento da relação pai-progênie auxilia na escolha do método de melhoramento, na decisão da intensidade de seleção e na previsão de ganho genético para os caracteres a serem selecionados. O objetivo deste trabalho foi estimar a herdabilidade para espessura de pericarpo, teor de sólidos solúveis e empalhamento de espiga em três populações de milho doce BR400, BR401 e BR402, usando famílias de meio irmãos e irmãos completos. A variabilidade genética foi evidenciada para todas os caracteres nas populações avaliadas. A herdabilidade estimada foi maior para espessura do pericarpo do que para sólidos solúveis totais e empalhamento de espiga nas populações estudadas. Como conseqüência, os ganhos genéticos esperados para a espessura do pericarpo serão maiores do que para os outros caracteres avaliados neste trabalho.

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