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COMBINING ABILITY ANALYSIS OF TOTAL SUGARS AND STARCH CONTENTS IN KERNELS OF SWEET CORN (*Zea mays* L.)

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ABSTRACT

Eight inbred lines of sweet corn were crossed to produce a non-reciprocal diallel set of crosses, i.e. 28 single crosses. The additive type of gene action was more important than the non-additive type in the inheritance of total sugars and starch contents in kernels at harvesting time and percentage of total sugars decrease and starch increase in kernels of green ears stored at room temperature (30±3°C) for 4 days. The narrow sense heritability estimates were 34.9% and 9.5% for total sugars content in kernels at harvesting and percentage of total sugars decrease after storage at room temperature, respectively. In addition, the narrow sense heritability estimates for starch content in kernels at harvesting time and percentage of starch increase in kernels of fresh ears stored at room temperature were 36.2% and 56.8%, respectively. Selection for the improvement of the above mentioned characters in the segregating generation should be performed according to family mean basis in replicated experiments, except in case of the percentage of starch increase in kernels of fresh ears stored at room temperature, whereas, single plant selection will be effective. Positive correlation coefficients were detected between percentage of total sugars in fresh kernels and each of ear position (r = 0.63) and ear length (r = 0.50), while the correlation was negative with each of number of days to tasseling (r = -0.48) and number of days to silking (r = -0.42). Furthermore, simple negative correlation (r = 0.69) was observed between percentage of starch content of kernels at harvest and percentage of starch increase in kernels of fresh ears stored at room temperature (30±3°C) for 4 days.

Key words: ***Sweet corn, Combining ability, Correlation, Heterosis, Heritability, Sugars, Starch***

INTRODUCTION

Sweet corn (*Zea mays* L.) is considered one of the ten most important vegetable crops (Kaukis and Davis 1986). It resulted from a mutation in chromosome 4 at the Su 1 locus of the cultivated corn, *Zea mays*

(Kaukis and Davis 1986, Hannah *et al* 1993 and Tracy 1999). Sweet corn has the potentiality to be an important vegetable crop for both local consumption and export in Egypt (El-Seidy 2001). The most important quality characteristics of sweet corn are, the high sweetness of kernels and the slow rate of sugar decrease in kernels during storage of ears after harvest (Kaukis and Davis 1986). In addition, low starch content of kernels is a desirable quality characteristic (Hassan 1989 and Suksoon *et al* 1999). Starch and sugars contents in kernels of sweet corn are quantitative characters (Hannah *et al* 1993 and Azanza *et al* 1996). However, Liu *et al* (1996) reported that sugar content in kernels of sweet corn was controlled by a pair of recessive genes and mentioned that no heterosis concerning total sugars content was observed in crosses among different sweet corn hybrids. Genetic differences in kernel sugars and starch contents were detected among sweet corn germplasm (Bonte and Jurik 1990, Wong *et al* 1994, Daneshvar and Dickinson 1999 and Suksoon *et al* 1999). The influence of the environmental effects on the sweetness of sweet corn kernels has been reported (Wong *et al* 1994 and 1995). Seed maturity and moisture seed content affected sugars seed content of sweet corn (Bar and Schaffer 1993, Kim *et al* 1994, Wong *et al* 1994, Borowski *et al* 1995 and Suksson *et al* 1999). Total sugars decrease in kernels of sweet corn during cold storage has been reported (Brecht *et al* 1990 and Olsen *et al* 1990). In addition, El-Seidy (2001) reported genotypic differences in the response of sweet corn cultivars to cold storage. Mazur *et al* (1999) reported success in improving sugar content of sweet corn kernels through selection.

The objective of the present study was to estimate different parameters required to design a successful breeding program to improve sweetness and shelf-life of sweet corn.

MATERIAL AND METHODS

This study was conducted in the Experimental Farm and Germplasm Preservation Laboratory of Horticulture Department, Faculty of Agriculture–Moshtohor, Zagazig University, Benha Branch, Moshtohor–Kalubia, Egypt and Research Station of Egypt HYTECH. Seed Company, Kalubia Egypt, during the successive seasons of 1999, 2000 and 2001.

Seven inbred lines of sweet corn, i.e. M-1-2, M-1-3, M-2-1, M-2-2, M-2-3, M-2-4 and M1 were obtained from the Germplasm Preservation Laboratory, Faculty of Agriculture- Moshtohor, Department of Horticulture, Moshtohor, Kalubia, Egypt. These lines were selected before the start of the present study, through selfing and single plant selection from a segregating population (F_2) derived from selfing of plants of the F_1 hybrid Merit, Asgrow Seed Company, U.S.A. In addition, SIO4 line (tropical inbred line from India) was obtained from the Germpalsm Preservation Laboratory, Moshtohor. The previously mentioned inbred lines were chosen to be used as parental genotypes in the present study based on the relatively wide variation in the different morphological and quality characters observed among these inbred lines. The different inbred parental genotypes were planted in the field for a final cycle of evaluation, selfing and single plant selection during summer of 1999.

The eight inbred lines, *i.e.* M-1-2, M-1-3, M-2-1, M-2-2, M-2-3, M-2-4, SIO4, and M1 were crossed during summer season of 2000 to produce a non–reciprocal diallel set of F_1 hybrids, *i.e.* 28 single crosses.

Seeds of the inbred parental lines and the 28 single crosses were planted in the field during summer season of 2001, in 3-ridges experimental plots. Each ridge was 5 m length and 70 cm width. Space between individual plants within each ridge was 30 cm. A randomized complete block design with 3 replicates was utilized in conducting this experiment. Plants were left to open pollination, except the plants of the third ridge in each of the 3- ridges experimental plots, whereas, tassels and silks of these plants were isolated by bergamine paper bags as soon as their appearance. Later, these individual plants were hand pollinated using pollen grains collected from plants within that ridge. This procedure was followed to avoid any possible direct (zenic) effects of foreign pollen grains on the chemical composition of kernels.

Different measurements were recorded on the individual plants of the first and second ridges in each of the 3 ridges-experimental plots except dry weight of 100 g kernels, total sugars and starch contents of kernels which were recorded on the plants of the third ridge which was assigned for the purpose of chemical analysis.

One hundred grams of kernels was obtained from two fresh huskless ears from two plants. Then the sample was placed in the drying oven at 70°C until the stabilization of the sample weight.

Directly after harvest, half huskless ears from four randomly selected individual plants were used to determine total sugars and starch contents. The other halve of the huskless ears were stored at room temperature (30±3°C) for 4 days. At the end of the storage period total sugars content in kernels was estimated according to Flodd and Priesty (1973), and starch content was determined according to the method described by Winton and Winton (1958).

Analysis of variance and correlation were performed according to Singh and Chaudhary (1979).

General and specific combining ability estimates were obtained by performing the Griffing's diallel cross analysis (Method 2), asdescribed by Griffing (1956).

Heterosis percentage was determined for individual crosses as deviation from the better parents (Bhatt. 1971).

The broad sense and narrow sense heritability estimates were estimated using formula suggested by Gardner (1963).

RESULTS AND DISCUSSION

Percentage of total sugars content in kernels at harvest

Data presented in Table (1) indicated that mean square values for percentage of total sugars content in kernels directly after harvest were significant for parental genotypes, F_1 hybrids and parental genotypes versus its F_1 hybrids. These results indicated the presence of genetic variability among parental genotypes and related F_1 hybrids. Bonte and Juvik (1990), Wong *et al* (1994) and Daneshvar and Dickinson (1999) reported genetic difference among sweet corn germplasm concerning sugars content of kernels.

Table 1. Mean square values for percentage of total sugars and starch seed contents at harvesting time and after 4 days for the different general and specific combining ability, and the ratio of general combining ability to the specific combining ability.

S.O.V.	df	Total sugars at harvesting	Total sugars reduction after 4 days	Starch at harvesting	Starch increase after 4 days
Rep	2	1.92	125.15	4.40	210.85
Genotypes	35	10.98**	1150.55**	32.40**	1818.42**
Parents	7	7.50**	615.20**	31.13**	1450.55**
Hybrids	27	12.24**	1319.25**	32.57**	1979.46**
Parents vs. Hybrids	1	1.50	343.27**	36.87**	45.08**
Error	70	0.13	9.80	1.46	50.56
General Combining Ability GCA	7	6.75**	459.78**	20.35**	365.97**
Specific Combining Ability SCA	28	2.98**	364.45**	8.41**	16.93**
Error	70	0.04	3.27	0.48	16.86
GCA/SCA		2.26	1.26	2.41	21.60

** Significant at 1 % level of significance

The results presented in Table (2) showed that the parental genotype M-1-2 had the highest percentage of total sugars content in kernels at harvesting time (14.2%), followed by M-2-4 (13.4%), M-2-3 (13.1%), M1 (12.1%), M-2-1 (11.0%), SIO4 (10.7%), M-1-3 (10.4%) and M-2-2 (9.9%). These results indicated that the parental genotype M-1-2 can be used as a source for genes controlling relatively high total sugars content in kernels. No significant differences were observed between total sugars content in fresh kernels of the F_1 hybrids M-1-3X M-2-1 (14.51%), M-2-1X M-2-2 (13.9%), M-2-1 X M-2-3 (13.8%), M-2-1 X M1 (13.7%), M-2-4 X M1 (14.0%) and the parental genotype M-1-2 (14.2%).

Table 2. Mean of percentage of total sugar and starch contents in kernels directly after harvesting and percentage of sugars reduction and starch increase after 4 days of storage at room temperature.

Genotypes	Total sugars at harvesting %	Total sugars reduction after 4 days%	Starch at harvesting %	Starch increase after 4 days
M-1-2	14.2	30.7	8.4	90.1
M-1-2 X M-1-3	13.6	41.9	10.0	70.3
M-1-2 X M-2-1	13.4	19.9	11.3	55.6
M-1-2 X M-2-2	11.8	64.9	10.3	86.7
M-1-2 X M-2-3	12.9	31.7	9.0	57.5
M-1-2 X M-2-4	13.4	22.4	3.0	91.3
M-1-2 X SIO4	10.6	77.2	4.9	91.5
M-1-2 X M1	12.3	47.1	10.1	93.0
M-1-3	10.4	27.8	11.6	46.2
M-1-3 X M-2-1	14.5	74.4	11.3	93.1
M-1-3 X M-2-2	12.9	9.2	12.0	19.6
M-1-3 X M-2-3	11.4	20.9	10.9	34.1
M-1-3 X M-2-4	7.7	72.5	11.3	67.2
M-1-3 X SIO4	6.7	59.5	18.0	32.6
M-1-3 X M1	7.7	52.6	13.7	43.0
M-2-1	11.0	28.7	6.1	91.5
M-2-1 X M-2-2	13.9	67.6	3.2	45.9
M-2-1 X M-2-3	13.8	50.8	9.9	84.6
M-2-1 X M-2-4	12.8	28.6	7.8	81.8
M-2-1 X SIO4	12.0	56.7	4.5	81.4
M-2-1 X M1	13.7	23.3	7.8	87.5
M-2-2	9.9	10.5	13.4	63.3
M-2-2 X M-2-3	12.8	38.2	10.5	65.6
M-2-2 X M-2-4	11.4	35.1	10.0	56.5
M-2-2 X SIO4	11.2	8.4	12.2	28.8
M-2-2 X M1	11.5	22.3	13.3	33.5
M-2-3	13.1	25.1	8.4	42.4
M-2-3 X M-2-4	13.6	12.1	10.7	26.9
M-2-3 X SIO4	12.6	16.6	9.1	38.7
M-2-3 X M1	12.5	24.7	11.0	38.1
M-2-4	13.4	47.7	11.1	68.9
M-2-4 X SIO4	13.6	31.6	7.1	88.8
M-2-4 X M1	14.0	28.5	5.4	79.6
SIO4	10.7	43.8	16.0	34.6
SIO4 X M1	12.0	15.7	9.3	36.9
M1	12.1	22.0	12.7	44.2
LSD 5%	0.6	11.5	2.0	11.6
LSD 1%	0.8	15.4	2.6	15.4

The results presented in Table (1) indicated that the mean square values for general and specific combining abilities were significant. The ratio of general combining ability to the specific combining ability (GCA/SCA) was 2.26 (Table 1). These results indicate the presence of both the additive and non-additive type of gene actions. However, the additive type of gene action was more important than the non– additive type in the inheritance of total sugars content in kernels of fresh sweet corn ears.

The results presented in Table (3) indicated that the parental genotype M-1-2 had the highest desirable general combining ability effect (0.78) followed by M-2-1 (0.76), M-2-3 (0.72) and M-2-4 (0.47). Such results indicate that these parental genotypes can be considered as good combiners in forming hybrids with relatively high total sugars in kernels of fresh sweet corn ears.

Table 3. General combining ability effects (g_i) for percentage of total sugars content in kernels at harvesting time and percentage of reduction after 4 days of storage at room temperature for deferent parental genotypes.

Parents	Total sugars at harvesting	Total sugars reduction after 4 days	Starch at harvesting	Starch increase after 4 days
M-1-2	0.78**	4.38**	-1.34**	19.15**
M-1-3	-1.40**	3.99**	2.17**	-10.03**
M-2-1	0.76**	10.38**	-2.09**	16.09**
M-2-2	-0.33**	-5.59**	0.96**	-8.89**
M-2-3	0.72**	-7.75**	-0.10	-12.19**
M-2-4	0.47**	0.35	-1.14**	7.78**
SIO4	-0.85**	3.07**	0.84**	-8.44**
M1	-0.14*	-8.80**	0.71**	-3.40**
LSD 5 % (gi)	0.12	1.06	0.41	2.42
LSD 1 % (gi)	0.16	1.42	0.55	3.22
LSD 5 % (gi-gj)	0.15	1.60	0.62	3.65
LSD 1 % (gi-gj)	0.25	2.14	0.82	4.86

Data presented in Table (4) indicated that the F_1 hybrid M-1-3 X M-2-1 had the highest desirable specific combining ability effect (3.08) followed by M-1-3 X M-2-2 (2.56), M-1-2 X M-1-3 (2.16) and M-2-1 X M-2-2 (1.41). These results indicated that such F_1 hybrids had relatively high total sugars content in kernels directly after harvesting. However, forming hybrids with other parental genotype combinations may result in obtaining better F_1 hybrids

Table 4. Specific combining ability effects(S_{ij}) for percentage of kernel total sugars and starch contents directly after harvesting and percentage of sugars reduction and starch increase after 4 days of storage at room temperature.

Crosses	Total sugar at harvesting	Total sugars reduction after 4 days	Starch at harvesting	Starch increase after 4 days
M-1-2 X M-1-3	2.16**	-2.38	-0.65	-0.45
M-1-2 X M-2-1	-0.20	-30.66**	4.91**	-41.01**
M-1-2 X M-2-2	-0.71**	30.24**	0.82	15.09**
M-1-2 X M-2-3	-0.67**	-0.77	0.58	-10.82**
M-1-2 X M-2-4	0.09	-18.22**	-4.41**	3.04
M-1-2 X SIO4	-1.43**	33.92**	-4.47**	19.43**
M-1-2 X M1	-0.40*	15.60**	0.84	33.90**
M-1-3 X M-2-1	3.08**	24.16**	1.32*	25.73**
M-1-3 X M-2-2	2.56**	-25.04**	-0.97	-22.87**
M-1-3 X M-2-3	0.01	-11.15**	-1.04	-5.04
M-1-3 X M-2-4	-3.44**	32.32**	0.40	8.05*
M-1-3 X SIO4	-3.12**	16.60**	5.18**	-10.33**
M-1-3 X M1	-3.53**	-2.30	0.98	-4.80
M-2-1 X M-2-2	1.41**	26.94**	-5.50**	-22.64**
M-2-1 X M-2-3	0.29	12.34**	2.22**	19.39**
M-2-1 X M-2-4	-0.49*	-18.03**	1.11	-3.41
M-2-1 X SIO4	0.06	7.42**	-4.12**	12.37**
M-2-1 X M1	1.02**	-14.00**	-0.70	13.40**
M-2-2 X M-2-3	0.34	15.67**	-0.20	25.33**
M-2-2 X M-2-4	-0.81**	4.50**	0.29	-3.71
M-2-2 X SIO4	0.31	-24.91**	0.53	-15.19**
M-2-2 X M1	-0.10	0.80	1.73**	-15.50**
M-2-3 X M-2-4	0.34	-16.39**	2.08**	-30.01**
M-2-3 X SIO4	0.66**	-14.59**	-1.47*	-2.03
M-2-3 X M1	-0.15	5.40**	0.47	-7.60*
M-2-4 X SIO4	1.91**	-7.68**	-2.46**	28.09**
M-2-4 X M1	1.60**	1.10	-4.05**	13.90**
SIO4 X M1	0.92**	-14.30**	-2.15**	-12.60**
LSD 5 % (Sij)	0.37	3.26	1.25	7.40
LSD 1 % (Sij)	0.50	4.34	1.67	9.86
LSD 5 % (Sij-sik)	0.56	4.83	2.47	10.96
LSD 1 % (Sij-sik)	0.74	6.43	1.75	14.59
LSD 5 % (Sij-skl)	0.53	4.55	1.76	10.33
LSD 1 % (Sij-skl)	0.69	6.06	2.33	13.76

The results presented in Table (5) indicated that the highest percentage of better parent heterosis values were associated with the F_1 hybrid M-1-3 X M-2-1 (31.82%) followed by M-1-3 X M-2-2 (24.04%) and M-2-1 X M-2-2 (26.36%). The kernel total sugars content of the involved parental genotypes should be considered to correctly evaluate such hybrids concerning this character .It has been reported by Liu *et al* (1996) that no heterosis concerning total sugars content was observed in crosses among different sweet corn hybrids. In addition, the different F_1 hybrids which showed better parent heterosis Table (5), indicate that the involved parental genotypes posses different genes controlling this character.

Table 5. Percentage of better parent heterosis in the F_1 generation for percentage of kernel sugars and starch contents at harvesting time and percentage of total sugars reduction and starch increase after 4 days of storage at room temperature.

Crosses	Total sugars at harvesting	Total sugars reduction after 4 days	Starch at harvesting	Starch increase after 4 days
M-1-2 X M-1-3	-4.22**	36.23*	19.0	52.2
M-1-2 X M-2-1	-5.63**	-62.02	85.2**	-38.3**
M-1-2 X M-2-2	-16.90	111.17**	22.6	36.9
M-1-2 X M-2-3	-9.16*	3.25	7.1	35.6
M-1-2 X M-2-4	-5.63	-53.14**	-64.3**	32.5*
M-1-2 X SIO4	-25.59**	76.33**	-41.7**	164.5**
M-1-2 X M1	-13.38**	53.14**	20.2	110.4**
M-1-3 X M-2-1	31.82**	41.53**	85.2**	101.5**
M-1-3 X M-2-2	24.04**	-66.75	3.4	-57.6**
M-1-3 X M-2-3	-12.98	-24.48	29.8	-19.6
M-1-3 X M-2-4	-42.54**	51.96**	1.8	45.5
M-1-3 X SIO4	-37.38**	35.92**	55.2**	-5.8
M-1-3 X M1	-42.15**	3.24**	18.1	-2.7
M-2-1 X M-2-2	26.36**	28.59**	-47.5**	-27.5**
M-2-1 X M-2-3	5.60**	-3.39**	62.3**	99.5**
M-2-1 X M-2-4	-4.48*	-45.66	27.9	18.7
M-2-1 X SIO4	9.39**	7.93**	-26.2**	135.3**
M-2-1 X M1	13.22**	-55.61	27.9	97.9**
M-2-2 X M-2-3	-2.29**	52.19**	25.0	54.7*
M-2-2 X M-2-4	-14.93	-26.39	-9.9*	-10.7
M-2-2 X SIO4	4.67**	-80.75**	8.9*	-16.8**
M-2-2 X M1	-4.96	1.52	4.7	-24.2**
M-2-3 X M-2-4	1.49**	-74.72**	27.4	-36.6**
M-2-3 X SIO4	-3.82*	-62.10**	8.3**	11.8
M-2-3 X M1	-4.58	-1.59	30.9	-10.1
M-2-4 X SIO4	1.49**	-33.79*	-36.0**	156.6**
M-2-4 X M1	4.48**	-40.22	-51.4**	80.1**
SIO4 X M1	-0.83*	-64.08**	-26.8**	6.6**

Data presented in Table (6) show that the broad sense heritability estimate (h^2_{bs}) for total sugar content in fresh ears was 99.0%. On the other hand the narrow sense heritability (h^2_{ns}) for the same character was 34.9%. These results indicated that the non-additive effects of gene action and the environmental effects play a role in the inheritance of this character. Based on these results, selection for high level of total sugars content in kernels of fresh ears in the segregating generations should be performed in replicated experiment to reduce the environmental effects on the expression of this character. It has been reported by Hannah *et al* (1993) and Azanza *et al* (1996) that sugars content of sweet corn kernels is a quantitative character. On the contrary, Liu *et al* (1996) found that sugars content in kernels of sweet corn was controlled by a pair of recessive genes. However, the important role of the environmental effects in the inheritance of this character has been reported (Wong *et al* 1994 and 1995). In addition, Mazur *et al* (1999) was successful in improving sugars content in kernels of sweet corn.

Table 6. The Broad (h^2_{bs}) and narrow (h^2_{ns}) sense heritability estimates for percentage of kernels sugars and starch contents directly after harvesting and percentages of total sugars reduction and starch increase in kernels after 4 days of storage at room temperature.

Characters	Heritability %	
	Broad Sense (h^2_{bs})	Narrow Sense (h^2_{ns})
Total sugars at harvesting	99.0	34.9
Total sugars reduction after 4 days	99.2	9.50
Starch at harvesting	96.3	36.2
Starch increase after 4 days	98.0	56.8

Percentage of kernel sugars reduction

Significant differences were detected among the different parental genotypes concerning the percentage of kernel sugars reduction after 4 days of storage at room temperature (30±3°C), (Table 1). Variations were observed among sweet corn germplasm concerning sugars content of kernels under cold storage (El-Seidy 2001).

The lowest percentage of kernel sugars reduction was associated with the parental genotype M-2-2 (10.5%) followed, in ascending order, by M1 (22.0%), M-2-3 (25.1%), M-1-3 (27.8%), M-2-1 (28.7%), M-1-2

(30.7%), SIO4 (43.81%) and M-2-4 (47.7%), (Table 2). Based on these results, the parental genotype M-2-2 can be considered the best source for genes controlling slow reduction in kernel sugars under the condition of storage at room temperature. Unfortunately, this parental inbred line, *i.e.*, M-2-2, had the lowest percentage of total sugars in fresh kernels, *i.e.*, 9.9% (Table, 2). In addition, the parental line which had the highest percentage of total sugars in fresh kernels, *i.e.*, M-1-2 (14.2 %), it had the highest ratio of sugar reduction in kernels stored at room temperature (Table 2). However, this will not reduce the value of both inbred lines, *i.e.*, M-2-2 and M-1-2 as breeding materials since the possible association between the high percentage of total sugars in fresh kernels and high percentage of total sugars reduction in kernels stored at room temperature (30±3°C) can be broken in the segregating generations of crosses between sweet corn genotypes. In addition, selection based on total sugars reduction in fresh kernels stored at room temperature condition is considered a very strong selection pressure since the common method of storing fresh sweet corn ears after harvest is under cold temperature. Total sugars decrease in kernels of sweet corn during cold storage has been reported (Brecht *et al* 1990 and Olsen *et al* 1990).

The results presented in Table (1) indicate the significance of both the general and specific combining abilities. In addition, the ratio of the general to specific combining ability was 1.26 (Table, 1). These results indicate the presence of both the additive and non-additive types of gene action effects on the inheritance of reduction rate in kernel sugars content under the condition of storing sweet corn fresh ears at room temperature. However, the additive type is more relatively important in the inheritance of this character. No reports have been found concerning the inheritance of sugars reduction rate in *Zea mays* kernels under the different storage conditions.

The most desirable general combining ability effects (gi) were associated with the parental genotypes M1 (-8.80), M-2-3 (-7.75), and M-2-2 (-5.59) (Table 3) which indicates that these parental genotypes can be considered as good combiners to form sweet corn hybrids characterized by slow kernel-sugar reduction under the condition of room temperature.

The F_1 hybrids M-1-2 X M-2-1 (-30.66), M-1-3 X M-2-2 (-25.04), and M-2-2 X SIO4 (-24.91) had the highest desirable specific combining ability effects (Table 4). Such F_1 hybrid are expected to have relatively long shelf life due to the slow decrease in total sugar content of kernels under the condition of fresh ear–storage at room temperature.

Based on the values of the better parent heterosis presented in (Table 5), the F_1 hybrids which showed practical value concerning slow sugar reduction in kernels of fresh ears stored at room temperature were M-2-3 X M-2-4 (-74.72%), M-1-3 X M-2-2 (-66.75%), SIO4 X M1(-64.08%), M-2-3 X SIO4 (-62.10 %), M-1-2 X M-2-1 (-62.02%), M-2-1 X M1 (-55.61%), and M-1-2 X M-2-4 (-53.14%).

The broad sense heritability for percentage of total sugar reduction in kernels of green ear stored at room temperature (30±3°C) for 4 days was 99.2%, while the value of the narrow sense heritability for the same character was 9.5%. (Table 6). The low narrow sense heritability estimate indicates the importance of the environmental effects on the expression of this character. Based on these results, the suggested method to achieve progress in improving this character is to select based on family mean basis in replicated experiments under different storage temperatures. This will lead to obtaining lines, open pollinated cultivars and/or F_1 hybrids with slow total sugar reduction in kernels of green sweet corn ears under different storage temperatures. It is worth mentioning here that many other factors could affect rate of sugars reduction in kernels of sweet corn in addition to the genetic control (Hannah *et al* 1993), such as harvesting time or seed maturity (Bar and Schaffer 1993, Kim *et al* 1994, Wong *et al* 1994, Borowski *et al* 1995 and Suksoon *et al* 1999) and moisture content of kernels (Borowski *et al* 1995). Such factors should also be considered in sweet corn breeding programs to improve such character.

Percentage of starch seed content in kernels at harvesting time

Results presented in Table (1) showed that the mean square values for percentage of starch seed content measured directly after harvesting were significant for parental genotypes, F_1 hybrids, and parents versus its F_1 hybrids which indicated the presences of genetic variation among such genotypes concerning this character. Genetic differences in kernel starch content have been observed among sweet corn germplasm (Bonte and Jurik 1990, Wong *et al* 1994, Daneshavar and Dickinson 1999 and Suksoon *et al* 1999).

The lowest percentage of starch seed content was associated with the parental genotype M-2-1 (6.1%), followed by, in ascending order, M-2-3 (8.4%), M-1-2 (8.4%), M-2-4 (11.1%) , M-1-3 (11.6%), M1 (12.7%), M-2-2 (13.4%), and SIO4 (16.0%), (Table 2). It is worth mentioning here, that the low percentage of starch seed content accompanied by high percentage of sugar seed content is considered as a desirable quality characteristic in sweet corn. Some of the obtained F_1 hybrids were significantly less in starch seed content than the parental genotypes (Table 2). The lowest percentage of starch seed content values measured directly after harvesting of ears were associated with the F_1 hybrids , M-1-2 X M-2-4 (3.0%), M-2-1 X M-2-2 (3.2%), and M-2-1 X SIO4 (4.5%), (Table 2). However, as mentioned before, kernel sugars content should be considered in the same time in order to judge such F_1 hybrids correctly.

The results presented in Table (1) indicate the significance of both the general and specific combining abilities for starch seed content measured directly after harvesting. In addition the ratio of general to specific combining ability was 2.41 These results indicate the presence of both the additive and non-additive type of gene actions in the inheritance of starch seed content measured directly after harvesting. However, the additive type of gene action is relatively more important in this respect.

The desirable general combining ability effects (gi) were associated the parental inbred lines M-2-1 (-2.09), M-1-2 (-1.34), and M-2-4 (-1.14), (Table 3). These results indicate that these parental genotypes can be considered as good combiners in forming hybrids with low kernel starch content measured directly after harvesting of green ears.

The highest desirable specific combining ability effects (Sij) were associated with the F_1 hybrids M-2-1X M-2-2 (-5.50), M-1-2X SIO4 (-4.47), M-1-2 X M-2-4 (-4.41) and M-2-1 X SIO4 and M-2-4 X M1 (-4.12), (Table, 4). Such F_1 hybrids will have low kernel starch content measured directly after harvesting of green ears.

The F_1 hybrids which showed relatively high better parent heterosis were M-1-2 X M-2-4 (-64.3%), M-2-4 X M1 (-51.4%), M-2-1 X M-2-2 (-47.5%), M-1-2 X SIO4 (-41.7%), and M-2-4 X SIO4 (-36.0%), (Table, 5). These F_1 hybrids will have low kernel starch content directly after harvesting green ears. However, other characteristics such as kernel sugars content should be considered before recommending any one of these F_1 hybrids.

The broad sense heritability estimate (h^2_{bs}) for starch seed content ; measured directly after harvesting was 96.3% while the narrow sense heritability estimate (h^2_{ns}) was 36.2% (Table 6). These results indicate tha the expression of this character is influenced by the non-additive type c gene interaction and the environmental conditions. It has been reported b Azanza *et al* (1996) that starch content of sweet corn kernels is quantitative character. Such information is of great value in sweet co breeding programs.

Percentage of kernel starch increase

The results presented in Table (1) indicate significant differences among the parental genotypes concerning the percentage of starch increase in kernels of fresh ears stored at room temperature (30±3°C) for 4 days. It is worth mentioning here that the slow rate of starch increase in kernels of sweet corn ears after harvest is considered one of the sweet corn quality characteristics. El-Seidy (2001) observed differences among sweet corn germplasm concerning starch content of kernels under cold storage.

The percentage of starch increase in the parental genotype ranged from 34.6 % (SIO4) to 91.5 % (M-2-1), (Table 2). The relatively low percentage of starch increase associated with the parental genotype SIO4 (34.6%) was accompanied by high percentage of sugar reduction (43.8%) in kernels of fresh ears stored at room temperature (30±3°C) for 4 days (Table, 2). In addition, the above-intermediate value of starch increase percentage found in kernels of the parental genotype M-2-2 (63.3%) was a accompanied by low percentage of sugars reduction (13.4%) after 4 days of storing the fresh green ears at room temperature (Table, 2). These results indicate that the rates of sugars reduction and starch increase in kernels of green ears after harvest are under different genetic control. Based on these results, rates of both sugar reduction and starch increase should be considered during selection to improve shelf life of sweet corn ears.

Mean square values for general and specific combining abilities were significant (Table, 1). The ratio of general combining ability to the specific combining ability was (21.60), (Table, 1). These results indicate the presence of both additive and non-additive type of gene actions in the inheritance of starch increase rate in kernels of green sweet corn ears after harvest. However, the additive type is more important than the non-additive type in the inheritance of this character.

The desirable general combining ability effects were associated with the parental genotypes M-2-3 (-12.19), M-1-3 (-10.03), M-2-2 (-8.89), and SIO4 (-8.44), (Table 3). These results indicate that the previously mentioned parental genotypes can be considered as good combiners in forming hybrids with slow starch increase rate in kernels after harvest of green sweet corn ears.

The F_1 hybrids which showed relatively high desirable specific combining ability effects were M-1-2 X M-2-1 (-41.01), M-2-3 X M-2-4 (-30.01), M-2-1 X M-2-2 (-22.64) , M-2-2 X M1 (-15.50),and M-2-2 X

SIO4 (-15.19), (Table, 4). Furthermore, relatively high better parent heterosis values were associated with the F_1 hybrids M-1-3 X M-2-2 (-57.6%) , M-1-2 X M-2-1 (-38.3%), M-2-3 X M-2-4 (-36.6%), M-2-1 X M-2-2 (-27.5 %), M-2-2 X M1 (-24.2%), M-1-3 X M-2-3 (-19.6%), and M-2-2 X SIO4 (-16.8%), (Table, 5). Such F_1 hybrids are expected to have relatively long shelf life due to the slow rate of starch increase in kernels of fresh sweet corn ears stored at room temperature (30±3°C) for 4 days. It is worth mentioning here that level of starch content of sweet corn kernels depends on harvesting time or degree of kernel maturity (Bar and Schaffer, 1993, Kim *et al* 1994, Wong *et al* 1994, Borowski *et al* 1995, Suksoon *et al* 1999).

The broad and narrow sense heritability estimates were 98.0% and 56.8 %, respectively, (Table 6). These results indicate the presence of the environmental effects on the rate of starch increase in kernels of fresh sweet corn ears after harvest. However, selection for slow rate of starch increase in kernels of sweet fresh sweet corn ears can be performed based on single plant selection because of the above-intermediate value of the narrow sense heritability observed in the present study for this character. Such information are of great value in sweet corn breeding programs to improve the shelf life of sweet corn ears.

Correlation Study

The simple correlation coefficient (r) values presented in Table (7) indicate positive correlation between weight of fresh husked ears/plant and each of plant height (r = 0.88), ear position on the plant (r = 0.63), and ear length (r = 0.81). In addition, negative correlation between weight of fresh husked ears/ plant and each of dry weight of 100 g fresh kernels (r = -0.49), number of days to tasselling (-0.84) and number of days to silking (r = -0.76). Such relationship should be considered by sweet corn breeders when selecting for high yield per plant.

The high positive correlation between number of days to silking and number of days to tasseling (r = 0.94) (Table 7) is a desirable correlation since selection for close silking and tasselling dates will lead to lines with well developed ears.

Positive correlation was observed between plant height and each of ear position (r = 0.70) and ear length (r = 0.63), (Table 7). Such information are of great value in breeding programs of sweet corn.

Positive correlation coefficients were detected between percentage of total sugars in fresh kernels and each of ear position (r = 0.63) and ear

Table 7. **Simple correlation coefficients between the different studied characters** [K]

Character	2	3	4	5	6	7	8	9	10	11	12
3	0.94**										
4	-0.71**	-0.63**									
5	-0.69**	-0.61**	0.69**								
6	0.39	0.28	-0.63**	-0.48*							
7	-0.55**	-0.65**	0.39	0.52**	0.11						
8	-0.86**	-0.79**	0.63**	0.69**	-0.29	0.41*					
9	-0.48*	-0.42*	0.19	0.67**	-0.31	0.27	0.50**				
10	0.31	0.21	-0.16	-0.62**	.0.35	0.10	-0.46**	-0.76**			
11	0.21	0.34	0.13	-0.12	-0.39	-0.33	-0.30	-0.25	0.26		
12	-0.01	-0.18	-0.25	-0.28	0.59**	0.42*	0.09	-0.13	0.33	-0.69**	
1	-0.84**	-0.76**	0.88**	0.63**	-0.49*	0.38	0.81**	0.26	-0.22	0.04	-0.15

k:

1-Weight of fresh husked ear / plant 2-Tasselling Date 3-Silking Date 4-Plant height
5-Position of 1st ear on plant (ear height) 6-Dry weight of fresh kernels
7-Number of rows/ear 8-Ear length
9- Percentage of total sugars content in kernels at harvesting time
10-Percentage of sugars reduction in kernels of fresh ears stored at room temperature
11-Percentage of starch seed content in kernels at harvesting time
12-Percentage of starch increase in kernels of fresh ears stored at room temperature
* Significant at 5% level
**Significant at 1% level

length (r = 0.50), (Table, 7) while, negative correlation coefficients were observed between percentage of total sugars content in fresh kernels and each of number of days to tasselling (r = -0.48) and number of days to silking (r = -0.42) (Table, 7). The significant correlation between some of the morphological characters and the percentage of total sugars in the fresh kernels will ease the selection for high sugars content of kernels in the segregating generations. Based on these results, selection for early tasselling and silking will be accompanied by indirect selection for high sugars content of kernels because of the correlation observed among these characters. In addition, selection for high total sugars in kernels of newly harvested sweet corn ears in the segregating generation will be accompanied by indirect selection for slow rate of total sugars reduction in kernels of fresh sweet corn ears stored at room temperature (30±3°C) for 4 days, because of the simple correlation observed between these two characters (r = -0.76) (Table 7). It is worth mentioning here that sugars content of kernels is considered the most important quality characteristic of sweet corn (Hassan, 1989, Suksson *et al* 1999). Moreover, simple negative correlation was observed between percentage of starch content of kernels and each of percentage of starch increase in kernels of fresh sweet corn ears stored at room temperature (30±3°C) for 4 days (r = -0.69), (Table, 7). Such information are of great value for sweet corn breeding programs to improve quality. However, path analysis needs to be performed in the future on the F_2 populations of the sweet corn F_1 hybrids obtained in the present study in order to develop an efficient selection index.

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تحليل القدرة على التآلف لمحتوى البذور من السكريات الكلية والنشا في الذرة السكرية

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أجريت عملية التهجين بين ٨ سلالات مرباة تربية ذاتية من الذرة السكرية لإنتاج ٢٨ هجين غير عكسي وتم تقييم السلالات الأبوية والهجين الناتجة ويمكن تلخيص النتائج في الآتي:-

- وجد أن التفاعل الجيني الإضافي كان أكثر أهمية في توريث صفة محتوى الحبوب من السكريات الكلية والنشا في الحبوب بعد الحصاد مباشرة ، وصفتي نقص السكريات الكلية ، وزيادة محتوى النشا في الحبوب بعد تخزين الكيزان بعد الحصاد على درجة حرارة الغرفة (٣٠±٣°م) لمدة ٤ أيام.
- وجد أن درجة التوريث بالمعنى الضيق كانت ٣٤,٩% و ٩,٥% لصفتي محتوى البذور من السكريات بعد الحصاد ، ونسبة الانخفاض في محتوى الحبوب بين السكريات الكلية بعد تخزين الكيزان الطازجة على درجة حرارة الغرفة (٣٠±٣°م) لمدة ٤ أيام على الترتيب.
- وجد أن درجة التوريث بالمعنى الضيق لصفتي محتوى الحبوب من النشا بعد الحصاد ونسبة الزيادة في محتوى الحبوب من النشا بعد تخزين الكيزان الطازجة على درجة حرارة الغرفة (٣٠ ±٣°م) لمدة ٤ أيام كانت ٣٦,٢% و٥٦,٨% ، والانتخاب لتحسين الصفات السابق ذكرها في الأجيال الإنعزالية لهجن الذرة السكرية التي تم عملها يجب أن يكون بناء على متوسط العائلة في تجارب ذات مكررات فيما عدا صفة نسبة الزيادة في محتوى الحبوب من النشا بعد تخزين الكيزان على درجة حرارة الغرفة حيث يكون انتخاب النباتات الفردية مجدي في هذه الحالة.
- وجد ارتباط موجب بين نسبة السكريات الكلية في الحبوب بعد الحصاد وكل من صفتي موضع الكوز على النبات (r = 0.63) و طول الكوز (r = 0.50) ، بينما كان الارتباط سالب مع صفتي عدد الأيام لظهور النورة المؤنثة (r = -0.42).
- وجد ارتباط سالب بين صفة محتوى الحبوب من النشا بعد الحصاد وصفة نسبة الزيادة في محتوى الحبوب من النشا بعد تخزين الكيزان على درجة حرارة الغرفة.

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