AcademicPres

Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic 1842-4309

Not Bot Horti Agrobo, 2013, 41(2):404-413

Notulae Botanicae Horti Agrobotanici
Cluj-Napoca

Genetic Variability and Association Analysis of Some Quantitative Characters in Sweet Corn

Ozlem ALAN[1]*, Gulcan KINACI[2], Engin KINACI[2], Imren KUTLU[3] Zekiye BUDAK BASCİFTCİ[2], Kenan SONMEZ[4], Yasemin EVRENOSOGLU[4]

[1]*Ege University, Odemis Vocational Training School, Izmir, Turkey; ozlem.alan@ege.edu.tr (*corresponding author)*

[2]*Eskisehir Osmangazi University, Faculty of Agriculture, Department of Field Crops, Eskisehir, Turkey; gkinaci@ogu.edu.tr; ekinaci@ogu.edu.tr; zbudak@ogu.edu.tr*

[3]*Eskisehir Osmangazi University, Faculty of Agriculture, Eskisehir, Turkey; ikutlu@ogu.edu.tr*

[4]*Eskisehir Osmangazi University, Faculty of Agriculture, Department of Horticulture, Eskisehir, Turkey; ksonmez@ogu.edu.tr; yevrenosoglu@ogu.edu.tr*

Abstract

The objective of this study was to determine genetic variability, heritability, genetic advance, genotypic and phenotypic correlations of yield, yield components and kernel quality traits in seven sweet corn varieties. The present research was conducted during 2009 and 2010 growing season in Eskisehir, midwestern Turkey. The trials were set up in randomised complete block design with four replications. Analysis of variance observed highly significant differences for all the examined traits in both years. Sugar content, soluble solid concentration and number of leaves per plant revealed the highest genotypic and phenotypic coefficient of variation values. The high heritability estimates coupled with high genetic advance for sugar content, soluble solid concentration and starch content. Positive correlations were revealed between yield (husked, dehusked and fresh kernel) and yield components except plant height and 1000 seed weight. Negative correlations were found between kernel quality and yield and yield related traits. It can be concluded that, husked ear weight and dehusked ear weight could be used as the main criteria for yield improvement. It should be unfeasible to develop sweet corn varieties with satisfactory yield potential and improved kernel quality for the different sweet corn markets.

Keywords: correlation coefficient, genetic advance, heritability, quality, sweet corn, yield

Introduction

Sweet corn (*Zea mays* L. *var. saccharata*) is a cultivated plant grown for fresh human consumption and raw or processed material of food industry throughout the world. Sweet corn differs from other corns (field, pop corn etc.). The primary difference is gene expression that determines endosperm carbohydrate content as well as many other genes that affect maize growth (Erdal *et al.*, 2011; Najeeb *et al.*, 2011; Znidarcic, 2012). It is produced for three distinct markets; fresh, canning and freezing. Production within these markets is largely independent of each other (Kleinhenz, 2008). Both total production and value of processed sweet corn has increased 60% over the last 25 years (Williams II, 2006). In Turkey, no information is available regarding the acreage of sweet corn grown. Despite the above-mentioned knowledge, interest in sweet corn has grown in recent years. Frozen sweet corn kernels are in the first rank among the fresh vegetables for import and frozen sweet corn export value was 36 tons in 2010 in Turkey (Aydın, 2011).

Sweet corn crops must meet strict market requirements for quality and appearance. While marketable yield, plant and ear height, and other characteristics are important to growers, the appearance and dimensions of ears and the sensory properties of kernels are important to consumers and these traits may be influenced by genotype, environment and in-field management (Rangarajan *et al.*, 2002; Kleinhenz, 2003).

The sweet corn breeders have often focused on improving quality and ear appearance, rather than on enhancing yield. Eating quality is a very complicated trait because of the effects of the individual gene influencing this trait, which is difficult to isolate and quantify. The polygenic nature of this trait has directed the breeding efforts towards the development of new sweet corn hybrids with improved eating quality and favourable ear and kernel traits (Tracy, 2003).

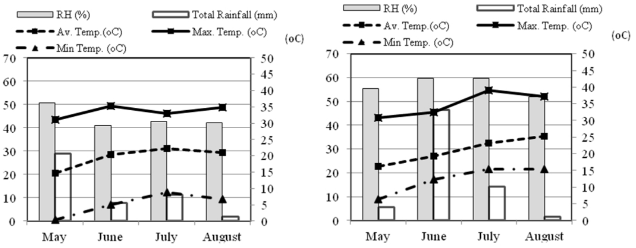
Knowledge of the relative magnitude of genetic parameters of yield, yield components and quality characters are important for an efficient breeding program. A character which have higher range of genetic variability, high heritability and high genetic advance would be an effective tool to improve yield. Therefore, for plant breeders it is essential to examine correlations to see the relationships between characters in order to decide for suitable selection criteria for a breeding program. Also, many sweet corn varieties are developed under environments which differ from those in target production areas. Therefore, assessing the relationships between characters in different locations and/or time is important to breeders. Yet, such studies are needed to develop better varieties with an emphasis on kernel quality and agronomic requirements to each specific market is required. The objective of this research was to determine genetic parameters, genotypic and phenotypic correlations of yield, yield components and kernel quality traits in sweet corn varieties.

Materials and methods

The field experiments were carried out in the experimental fields of Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir (39°46'N; 30°33'E; 801 m above sea level) during 2009 and 2010 growing season.

Climatic conditions during the experiment were given in Fig. 1(a) and 1(b). The soil was sandy clay (44% sand; 20% clay) with 1% organic matter, 0.05% total salt, 5% lime and pH 7.6. Seven sweet corn varieties (*Lumina*, *Merit*, *Sunshine*, *Jubile*, *Challenger Yellow Baby* and 2201) were used as materials.

Each cultivar was sown in randomized complete block with four replications and each experimental plot was 29.4 m^2. Seeds were sown on April 29 in 2009 and on May 19 in 2010, in a spacing of 70 cm x 25 cm. Plants were fertilized with equivalent to 280 kg N, 110 kg P_2O_5 and 110 kg K_2O per hectare (Turgut, 2000) during growing season. The drip irrigation was applied as needed and weeds were controlled mechanically by hand. No fungicide and insecticide were applied during cultivation.



(a) (b)

Fig. 1. Climatic conditions during (a) 2009 and (b) 2010

Plant height and number of leaves per plant were recorded on the whole plot basis. When the sweet corn reached harvest maturity (juice consistecy of kernels) twenty ears from in the centre of each replication were harvested randomly by hand in the morning.

These ears were taken to the processing lab and divided into the following categories for measurements: ten for ear traits, ten for kernel quality traits. Husked ear weight, dehusked ear weight, ear length, ear diameter, number of rows per ear, number of kernels per row were recorded for ear traits. Husked ear yield was calculated from husked ear weight, dehusked ear yield was calculated from dehusked ear weight. Approximately 2 months after harvesting as International Seed Testing Association (ISTA, 1999) suggests, 1000 seed weight was calculated by counting 8 replicated 100 seeds from each plot and was weighted in g and the mean was multiplied with 10.

For kernel quality traits, within one hour after harvest, kernels were cut from the ear and the following measurements are recorded; fresh kernel weight, dry matter content, soluble solid concentration, protein content, sugar content and starch content. Fresh kernel yield was calculated from fresh kernel weight. Kernels dried in an oven at 65 °C weight loss between measurements was < 0.05 g. The percentage difference between fresh and dry weights was used as the dry matter content of the kernel. Extract was prepared for soluble solid concentration using modified methods of Hale *et al.* (2005) and determinated with the use of a digital refractometer. Kernel protein content was determinated by kjeldahl method (Kirk and Sawyer, 1991). Kernel sugar content was determinated by the Lane-Eynon Method (Kirk and Sawyer, 1991). Kernel starch content was determinated by polarimetric method (Earle and Milner, 1944).

To estimate the extent of magnitude of variation among examined traits, all data were subjected to analysis of variance. Mean, standard error, range were analyzed according to Singh and Chaudhary (1985). Components of variance σ^2g= genotypic variance and σ^2p= phenotypic variance were estimated using the following formula (Wricke and Weber, 1986).

The genotypic and phenotypic coefficient variations were calculated as the square root of genotypic and phenotypic variances divided by the mean of traits and multiplying by 100.

Genotypic coefficient of variation:

$$(\mathbf{GCV}) = \surd(\text{"}\sigma\text{"}\ {}^{\uparrow}2\ \mathrm{g})/X \quad \mathrm{x} \quad 100;$$

Phenotypic coefficient of variation:

$$(\mathbf{PCV}) = \surd(\text{"}\sigma\text{"}\ {}^{\uparrow}2\ \mathrm{p})/X \quad \mathrm{x}\ 100$$

where, σ^2p, σ^2g and X are the phenotypic and genotypic standard deviation and mean value of the traits, respectively. Heritability in broad sense (h^2) was estimated as the ratio of genotypic variance to the phenotypic variance described by Hanson *et al.* (1956) as: Heritability (h^2)= (σ^2g)/ (σ^2p)

Expected genetic advance (GA) and GA as percent of the mean calculated according to Shukla *et al.* (2006).

$GA= i\, \sigma^2 p\, h^2$ $\quad$ $GA(\%) = GA/X*100$

Where, i= efficacy of selection which is 2.06 at 5% selection intensity; σ^2p= phenotypic standard deviation; h^2= heritability in broad sense. Genotypic (r_g) and phenotypic (r_F) correlation coefficient between x and y traits were calculated based on the procedure described by Kempthorne (1973).

$$\mathbf{rg\,(x,y)} = \frac{\mathbf{COVg\,(x,y)}}{\sqrt{\boldsymbol{\sigma}\mathbf{2g(x)}\,.\,\boldsymbol{\sigma}\mathbf{2g(y)}}}$$

where, $COV_{xy}(g)$ and, $COV_{xy}(p)$ are genotypic and phenotypic covariance between x and y characters, σ^2g= genotypic variance, σ^2p= phenotypic variance.

Results and discussions

Genetic variability: The range, mean, standard error, critical differences, coefficient of variation, genotypic and phenotypic variance, genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV), broad sense heritability (h^2) and genetic advence in a percentage mean (GA) were given in Tab. 1 and 2.

Highly significant differences were observed for all the examined traits in both years. In 2009, husked ear yield ranged from 19.4-29.3 ton per hectare, dehusked ear yield 19.4-24.6 ton per hectare, fresh kernel yield 14.2-20.9 ton per hectare, plant height 176-232 cm, number of leaves per plant 5.4-11.7, husked ear weight 418-525 g, dehusked ear weight 340-430 g, ear length 20-25 cm, ear diameter 45-55 mm, number of rows per ear 16-22, number of kernels per row 38-47, 1000 seed weight 120-178 g, dry matter content 32.4-40.0%, soluble solid concentration 14.4-28.5%, protein content 9.6-13.5%, sugar content 3.1-10.0% and starch content 13.0-20.0%. In the second year of the experiment, husked ear yield ranged from 21.5-30.8 ton per hectare, dehusked ear yield 18.4-23.1 ton per hectare, fresh kernel yield 13.3-17.8 ton per hectare, plant height 182-237 cm, number of leaves per plant 8.8-12.2, husked ear weight 393-539 g, dehusked ear weight 321-403 g, ear length 21-25 cm, ear diameter 49-56 mm, number of rows per ear 15-21, number of kernels per row 38-46, 1000 seed weight 127.3-189-8 g, dry matter content 29.5-44.2%, soluble solid concentration 11.6-31.0%, protein content 8.9-14.7%, sugar content 3.2-8.6% and starch content 11.6-19.1% (Tab. 2). The presented results revealed that the genotypes were differed significantly for investigated yield, yield related traits and kernel quality traits indicating a considerable range of genetic variability.

The values of PCV were higher than the corresponding GCV values for all characters, the differences between them were low for the most of the studied traits (Tab. 1 and 2). This indicates that almost all of the characters are more influenced by the environment. Similar results have been reported by Asghar and Mehdi (1999), Saleh *et al.* (2002) in sweet corn and Hefny (2011) in corn. The highest GCV and PCV values were recorded for sugar content, soluble solid concentration and number of leaves per plant in 2009 (Tab. 1); sugar content and soluble solid concentration in 2010. In both years, the lowest GCV and PCV values were obtained from ear length, ear diameter, dry matter content and number of kernels per row. (Tab. 1 and 2). Hefny (2011) reported that high GCV estimates are an indicative of less amenability of these traits to environmental fluctuations and greater emphasis should be given to these characters, while breeding cultivars from the present material.

Estimates of heritability in broad sense changed between 41.4% for ear length to 99% for dehusked ear yield and dehusked ear weight in 2009 (Tab. 1); and between 32.5% for dry matter content to 97.9% for sugar content in 2010 (Tab. 2). GA was highest for sugar content (2.76%), which was followed by soluble solid concentration (1.33%), number of leaves per plant (1.10%), protein content (0.76%), starch content (0.73%), husked ear yield (0.65%), dehusked ear yield (0.60), while it was lowest for ear length (0.16%) in 2009 (Tab. 1).

In 2010, GA was highest for sugar content (2.70%), which was followed by soluble solid concentration (1.89%), starch content (0.92%), number of rows per ear (0.63%) etc., while it was lowest for dry matter content (0.19%) (Tab. 2). Johnson *et al.* (1955) suggest that estimates of heritability and genetic advance should always be considered simultaneously because high heritability will not always associate with high GA. The sugar content and soluble solid concentration observed high heritability (>80%) with high GA; protein content, starch content, husked ear yield, dehusked ear yield, husked ear weight, dehusked ear weight accompanied with high heritability (>80%) and moderate GA in 2009 (Tab. 1). Similar results were obtained in 2010; sugar content, soluble solid concentration and starch content observed high heritability (>80%) with high GA; husked ear weight, dehusked ear weight, dehusked ear yield, fresh kernel yield and number of rows per ear accompanied with high heritability (>80%) and moderate GA (Tab. 2). Low heritability was associated with low GA for dry matter content and 1000 seed weight, in both years (Tab. 1 and 2).

In this study, the high heritability estimates coupled with high GA for sugar content, soluble solid concentration and starch content indicating that these characters can be considered as favorable attributes for improvement through selection and this may due to additive gene action (Panse 1957). Rosenbrook and Andrew (1971) also reported the additive gen action could be significant for sucrose and phytoglycogen accumulation in kernel. Traits with high heritability and moderate genetic advance (husked ear yield, dehusked ear yield, husked ear weight, dehusked ear weight, number of rows per ear) are considered not suitable for genetic improvement through selection under such conditions. Traits with low heritability and GA (dry matter content and 1000 seed weight) are limited for genetic improvement through selection (Hefny 2011).

Correlation coefficient: The genotypic and phenotypic correlation coefficients were presented in Tab. 3 and 4. In general, genotypic correlation coefficients were higher than corresponding phenotypic ones for most of the characters in both years. 17% of genotypic correlations and 6% of phenotypic correlations were statistically significant

(Tab. 3 and 4). The utilize selection based on genotypic correlation is an effective instrument for examining degree of relationships among traits due to phenotypic correlation obtain from genotype and environment interaction (Eşiyok *et al*., 2011).

Significant correlations were estimated between yield and yield components for both years in this study (Tab. 3 and 4). In the first year of the experiment, husked ear yield was positively and significantly correlated with number of leaves per plant, husked ear weight and ear length (with correlation coefficients of 0.79, 1.00, and 1.00, respectively). Dehusked ear yield was positively and significantly correlated with fresh kernel yield, dehusked ear weight and ear length (with correlation coefficients of 0.89, 1.00 and 0.82, respectively). Fresh kernel yield had significant positive correlations with dehusked ear weight (0.89) and ear diameter (0.79). Number of leaves per plant was positively and highly correlated with husked ear weight. Husked ear weight and dehusked ear weight had positive significant correlations with ear length. Ear length was significantly and positively correlated with number of kernels per row (Tab. 3).

In the second year of the experiment, the relationships among yield and yield related traits were slightly different (Tab. 4). Husked ear yield had positive and significant correlation with dehusked ear yield, husked ear weight, dehusked ear weight and number of kernels per row (with correlation coefficients of 0.82, 1.00, 0.82 and 0.82, respectively).

Dehusked ear yield was positively and significantly correlated with fresh kernel yield, husked ear weight, dehusked ear weight, ear diameter, number of kernels per row (with correlation coefficients of 0.97, 0.88, 1.00, 0.82 and 0.79, respectively). Fresh kernel yield was positively and significantly correlated with husked ear weight, dehusked ear weight, ear diameter, number of rows per ear (with correlation coefficients of 0.75, 0.98, 0.92 and 0.82, respectively). Plant height had positive and significant association with ear length. Positive and significant correlation was existed between husked ear weight and dehusked ear weight. Ear diameter and number of rows per ear had positive significant correlations with dehusked ear weight (Tab. 4).

Yield and yield related traits revealed that husked ear yield was positively correlated with dehusked ear yield and dehusked ear yield was positively correlated with fresh kernel yield for both years (Tab. 3 and 4). These results are in close agreement with earlier report of Kashiani et al. (2010). Positive correlations were found between yield (husked, dehusked and fresh kernel) and yield components except plant height and 1000 seed weight (Tab.3 and 4). This indicates that high measurements of these traits had direct positive contribution to sweet corn yield and its possible to simultaneous improvement husked, dehusked or fresh kernel yield with these characters. Similar findings reported by Wong *et al*. (1994); Saleh *et al*. (2002); Kashiani *et al*. (2008); Öktem (2008); Kashiani *et al*. (2010); Khazaei *et al*. (2010); İlker (2011) in sweet corn and Kabdal *et al*. (2003) and Hefny (2011) in corn.

In this study, no significant correlation was obtained between plant height and yield. These results are in agreement with the findings of Asghar and Mehdi (1999) and Öktem (2008). On the other hand, Saleh *et al*. (2002); Kashiani (2010) and İlker (2011) reported that plant height had positive and significant association with yield.

Also, significant correlations were estimated between yield-yield components and kernel quality for both years in this study (Tab. 3 and 4). Negative correlations were found between number of leaves per plant and dry matter content; ear length and dry matter content; number of kernels per row and dry matter content in 2009; fresh kernel yield and sugar content; plant height and sugar content in 2010. Positive correlations were existed between plant height and starch content; 1000 seed weight and dry matter content in 2009; 1000 seed weight and dry matter content; 1000 seed weight and soluble solid concentration; plant height and starch content in 2010. Similar negative correlations reported between yield and yield components and kernel quality traits (Wong *et al*., 1994; Saleh *et al*., 2002; Solomon, 2011). This indicates that the difficulty of simultaneous improvement of sweet corn for both yield ability and kernel quality (Ha, 1999; Saleh *et al*., 2002). On the other hand, non significant correlations between kernel quality and yield related traits reported by Khanduri *et al*. (2010), suggesting the potential for improvement of kernel sugar concentration independent of yield.

Kernel quality traits revealed that they were correlated among themselves for both years (Tab. 3 and 4). Positive and significant correlations were found between soluble solid concentration and starch content; dry matter content and soluble solid concentration. On the other hand, non-significant correlations between soluble solid concentration and starch content were reported by Kumari *et al*. (2006). Negative associations were existed between sugar content and starch content; protein content and starch content; soluble solid concentration and protein content. This kind of associations were also observed by Dudley and Lambert (1992); Ha (1999), Kumari *et al*. (2006). Many authors stated that soluble solid concentration has been utilised as a rapid, pre-harvest method to determine fresh sweet corn sugar content (Kleinhenz, 2003; Zhu *et al*., 1992). Kumari *et al*. (2006) also reported total sugar, reducing sugar and non-reducing sugar content were positively and significantly correlated with soluble solid concentration. In contrast, Hale *et al*. (2005) reported that an overall R^2 of -0.99 between soluble solid concentration and total sugars; soluble solid cannot be used as a reliable indicator of sweet corn total sugar concentrations. In this study, non-significant but negative correlations were estimated between soluble solid concentration and sugar content.

Tab. 1. Genetic parameters of yield, yield components and kernel quality in sweet corn (2009)

	Range	Mean square	Mean	SE (±)	CD	CV (%)	σ^2 g	σ^2p	GCV (%)	PCV (%)	h^2 (%)	GA (%)
Yield and Yield Components												
Husked ear yield (ton ha^{-1})	19.4 ± 29.3	51.60**	22.8	0.42	0.87^1 1.20^2	0.23	4.38	4.72	0.33	0.34	92.8	0.65
Dehusked ear yield (ton ha^{-1})	19.4 ± 24.6	403.08**	21.2	0.12	0.26 0.35	0.07	2.99	3.02	0.29	0.29	99.0	0.60
Fresh kernel yield (ton ha^{-1})	14.2 ± 20.9	6.08**	16.0	0.78	1.65 2.26	0.52	1.56	2.79	0.28	0.37	55.9	0.43
Plant height (cm)	176 ± 232	8.00**	206.6	6.68	14.03 19.21	1.24	156.07	245.20	0.22	0.27	63.7	0.35
No. of leaves/plant	5.4 ± 11.7	13.14**	8.0	0.56	1.17 1.60	0.53	1.87	2.49	0.62	0.71	75.1	1.10
Husked ear weight (g)	418 ± 525	53.08**	481.4	7.15	15.02 20.58	0.87	1331.49	1433.76	0.27	0.28	92.9	0.54
Dehusked ear weight (g)	340 ± 430	404.66**	371.3	2.12	4.45 6.10	0.29	906.23	915.21	0.29	0.29	99.0	0.59
Ear length (cm)	20 ± 25	3.80*	22.5	0.63	1.32 1.80	0.35	0.55	1.33	0.12	0.18	41.4	0.16
Ear diameter (mm)	44.9 ± 55.0	8.38**	48.7	1.12	2.36 3.23	0.43	4.63	7.15	0.16	0.20	64.8	0.26
No. of rows/ear	16 ± 22	6.15**	18.5	0.77	1.61 2.20	0.48	1.51	2.68	0.24	0.32	56.3	0.37
No. of kernels/row	38 ± 47	15.35**	42.3	0.81	1.70 2.33	0.33	4.68	5.99	0.18	0.21	78.1	0.33
1000-seed weight (g)	120 ±178	4.13**	139.9	8.72	18.32 25.09	1.97	122.27	274.29	0.28	0.42	44.6	0.39
Kernel Quality												
Dry matter content (%)	32.4 ± 40.0	11.26**	35.5	0.82	1.72 2.35	0.37	3.42	4.75	0.19	0.22	72.0	0.33
Soluble solid concentration (%)	14.4 ± 28.5	62.83**	21.7	0.73	1.53 2.10	0.42	16.40	17.46	0.67	0.69	93.9	1.33
Protein content (%)	9.6 ± 13.5	79.89**	11.1	0.19	0.39 0.53	0.15	1.37	1.44	0.38	0.39	95.1	0.76
Sugar content (%)	3.1 ± 10.0	77.39**	5.4	0.34	0.71 0.97	0.39	4.32	4.55	1.37	1.41	94.9	2.76
Starch content (%)	13 ± 20	20.39**	17.5	0.61	1.29 1.76	0.39	3.64	4.40	0.39	0.43	82.7	0.73

SE: Standard error, CD: critical difference, ^{1}5% and ^{2}1%, CV:coefficient of variation, σ^2 g: genotypic variances, σ^2p: phenotypic variances, GCV: genotypic coefficient of variation, PCV: phenotypic coefficient of variation, h^2: broad-sense heritability, GA: genetic advance, *,**significant at 5% and 1% probability level respectively

Tab. 2. Genetic parameters of yield, yield components and kernel quality in sweet corn (2010)

	Range	Mean square	Mean	SE (±)	CD	CV(%)	σ^2 g	σ^2p	GCV (%)	PCV (%)	h^2 (%)	GA (%)
					Yield and Yield Components							
Husked ear yield (ton ha^{-1})	21.5 ± 30.8	7.84**	26.3	1.15	2.42^1 3.32^2	0.60	4.54	7.19	0.29	0.36	63.1	0.47
Dehusked ear yield (ton ha^{-1})	18.4 ± 23.1	20.11**	20.6	0.51	1.08 1.48	0.30	2.53	3.06	0.28	0.30	82.7	0.52
Fresh kernel yield (ton ha^{-1})	13.3 ± 17.8	21.66**	15.5	0.44	0.91 1.15	0.30	1.96	2.33	0.32	0.35	84.1	0.61
Plant height (cm)	182 ± 237	16.14**	214.6	5.06	10.63 14.57	0.92	193.96	245.19	0.23	0.26	79.1	0.42
No. of leaves/plant	8.8 ± 12.2	11.13**	10.3	0.38	0.80 1.09	0.32	0.73	1.01	0.30	0.35	72.3	0.52
Husked ear weight (g)	393 ± 539	28.64**	464.3	11.02	23.14 31.70	1.37	1676.63	1919.31	0.31	0.34	87.4	0.61
Dehusked ear weight (g)	321 ± 403	20.03**	359.8	8.98	18.88 25.86	1.27	767.85	929.29	0.28	0.30	82.6	0.52
Ear length (cm)	21.3 ± 25.1	11.17**	23.1	0.39	0.82 1.13	0.22	0.78	1.09	0.14	0.16	71.6	0.24
Ear diameter (mm)	49 ± 56	19.21**	52.3	0.65	1.37 1.88	0.24	3.87	4.71	0.13	0.15	82.2	0.25
No. of rows/ear	15 ± 21	21.45**	17.6	0.51	1.08 1.48	0.33	2.70	3.23	0.33	0.36	83.6	0.63
No. of kernels/row	38 ± 46	7.46**	41.6	1.11	2.33 3.20	0.46	3.98	6.45	0.17	0.22	61.7	0.28
1000-seed weight (g)	127.3 ± 189.8	5.05**	158.5	9.83	20.65 28.29	2.09	195.68	388.87	0.32	0.44	50.3	0.46
					Kernel Quality							
Dry matter content (%)	29.5 ± 44.2	2.93*	36.7	1.67	3.51 4.81	0.74	2.69	8.27	0.16	0.28	32.5	0.19
Soluble solid concentration (%)	11.6 ± 31.0	58.21**	22.2	1.11	2.32 3.18	0.63	35.03	37.48	0.95	0.98	93.5	1.89
Protein content (%)	8.9 ± 14.7	8.11**	11.1	0.57	1.19 1.63	0.46	1.14	1.78	0.34	0.43	64.0	0.57
Sugar content (%)	3.2 ± 8.6	201.62**	4.9	0.18	0.38 0.52	0.22	3.25	3.32	1.33	1.34	97.9	2.70
Starch content (%)	11.6 ± 19.1	24.53**	15.9	0.63	1.32 1.80	0.42	4.62	5.41	0.48	0.52	85.4	0.92

SE: Standard error, CD: critical difference, ^{1}5% and ^{2}1%, CV:coefficient of variation, σ^2 g: genotypic variances, σ^2p: phenotypic variances, GCV: genotypic coefficient of variation, PCV: phenotypic coefficient of variation, h^2: broad-sense heritability, GA: genetic advance, *,**significant at 5% and 1% probability level respectively

Table 3. Genotypic and phenotypic correlation coefficients of yield, yield components and kernel quality traits among sweet corn genotypes in 2009.

Traits		Husked ear yield	Dehusked ear yield	Fresh kernel yield	Plant height	No. of leaves/ plant	Husked ear weight	Dehusked ear weight	Ear length	Ear diameter	No. of rows/ear	No. of kernels/ row	1000-seed weight	Dry matter content	Soluble solid concentration	Protein content	Sugar content
Yield and Yield Components																	
Dehusked ear yield	G*	0.69															
	P	0.67															
Fresh kernel yield	G	0.54	0.89**														
	P	0.39	0.68														
Plant height	G	0.42	0.21	0.25													
	P	0.43	0.18	0.33													
No. of leaves/ plant	G	0.79*	0.36	0.55	0.62												
	P	0.68	0.32	0.48	0.65												
Husked ear weight	G	1.00**	0.69	0.54	0.42	0.79**											
	P	1.00**	0.67	0.40	0.33	0.68											
Dehusked ear weight	G	0.70	1.00**	0.89**	0.21	0.36	0.69										
	P	0.67	1.00**	0.69	0.18	0.32	0.67										
Ear length	G	1.00**	0.82*	0.71	0.43	0.71	1.00**	0.82*									
	P	0.62	0.52	0.23	0.13	0.33	0.62	0.52									
Ear diameter	G	0.14	0.62	0.79*	0.41	0.11	0.14	0.62	0.04								
	P	0.09	0.51	0.53	0.24	0.08	0.09	0.50	-0.02								
No. of rows/ear	G	0.24	0.57	0.71	0.08	0.38	0.24	0.58	0.33	0.14							
	P	0.18	0.41	0.34	-0.07	0.18	0.18	0.41	0.26	-0.02							
No. of kernels/row	G	0.70	0.45	0.30	0.61	0.60	0.74	0.45	1.00**	-0.07	0.13						
	P	0.64	0.42	0.29	0.51	0.48	0.64	0.42	0.58	-0.08	0.01						
1000-seed weight	G	-0.17	0.31	-0.04	-0.29	-0.51	-0.17	0.30	-0.40	0.55	0.12	-0.58					
	P	-0.09	0.21	0.09	-0.22	-0.30	-0.09	0.21	-0.23	0.23	-0.02	-0.41					
Kernel Quality																	
Dry matter content	G	-0.70	-0.21	-0.41	-0.56	-0.88**	-0.70	-0.22	-0.79*	0.07	0.07	-0.79*	0.86*				
	P	-0.60	-0.21	-0.38	-0.34	-0.61	-0.60	-0.21	-0.53	-0.06	0.08	-0.62	0.42				
Soluble solid concentration	G	-0.18	0.009	-0.27	0.37	-0.21	-0.19	0.01	-0.08	-0.06	0.39	0.12	0.26	0.51			
	P	-0.16	0.012	0.17	0.30	-0.14	-0.16	0.01	-0.12	-0.04	0.26	0.08	0.19	0.40			
Protein content	G	0.12	-0.08	0.01	-0.69	-0.01	0.12	-0.08	-0.03	-0.19	-0.33	-0.30	-0.04	-0.20	-0.93**		
	P	0.10	-0.08	0.01	-0.56	-0.36	0.10	-0.08	0.02	-0.11	-0.23	-0.26	-0.05	-0.19	-0.88**		
Sugar content	G	0.19	-0.36	-0.58	-0.44	0.02	0.20	-0.36	-0.06	-0.61	-0.56	-0.15	-0.05	-0.12	-0.49	0.71	
	P	0.20	-0.35	-0.44	-0.36	0.02	0.20	-0.35	-0.04	-0.47	-0.35	-0.13	-0.07	-0.13	-0.44	0.69	
Starch content	G	0.16	0.15	0.06	0.92**	0.25	0.13	0.15	0.18	0.26	0.16	0.49	-0.04	-0.05	0.81*	-0.98**	-0.59
	P	0.07	0.15	0.01	0.66	0.12	0.11	0.15	0.17	0.22	0.06	0.44	-0.05	-0.06	0.70	-0.86*	-0.56

*G: genetic correlation coefficient, P: phenotypic correlation cofficient.*,** Significant at 5% and 1% probability level, respectively

Tab. 4. Genotypic and phenotypic correlation coefficients of yield, yield components and kernel quality traits among sweet corn genotypes in 2010.

Traits		Husked ear yield	Dehusked ear yield	Fresh kernel yield	Plant height	No. of leaves/ plant	Husked ear weight	Dehusked ear weight	Ear length	Ear diameter	No. of rows/ ear	No. of kernels/ row	1000-seed weight	Dry matter content	Soluble solid concentration	Protein content	Sugar content
Yield and Yield Components																	
Dehusked ear yield	G*	0.82**															
	P	0.74															
Fresh kernel yield	G	0.65	0.97**														
	P	0.62	0.93**														
Plant height	G	0.17	0.33	0.44													
	P	0.16	0.34	0.43													
No. of leaves/ plant	G	0.39	0.15	0.19	0.44												
	P	0.32	0.14	0.16	0.35												
Husked ear weight	G	1.00**	0.88**	0.75*	0.12	0.27											
	P	0.89**	0.85*	0.71	0.08	0.21											
Dehusked ear weight	G	0.82*	1.00**	0.98**	0.33	0.15	0.88**										
	P	0.74	1.00**	0.93**	0.34	0.14	0.86**										
Ear length	G	0.32	-0.08	-0.31	-0.77*	-0.44	0.32	-0.08									
	P	0.18	-0.08	-0.22	-0.62	-0.35	0.20	-0.08									
Ear diameter	G	0.36	0.82*	0.92**	0.27	0.40	0.44	0.83*	-0.45								
	P	0.37	0.80*	0.86*	0.28	0.21	0.49	0.81*	-0.37								
No. of rows/ear	G	0.53	0.79*	0.82*	0.28	-0.13	0.53	0.80*	-0.14	0.52							
	P	0.46	0.77*	0.73	0.29	-0.12	0.52	0.77*	-0.15	0.54							
No. of kernels/row	G	0.82*	0.22	0.07	0.22	0.53	0.62	0.22	0.45	-0.36	0.02						
	P	0.52	0.26	0.11	0.12	0.44	0.51	0.26	0.29	-021	0.07						
1000-seed weight	G	-0.01	0.53	0.59	0.36	-0.36	0.13	0.53	-0.50	0.74	0.50	-0.64					
	P	-0.08	0.30	0.37	0.24	-0.26	0.08	0.30	-0.30	0.47	0.41	-0.35					
Kernel Quality																	
Dry matter content	G	0.08	0.37	0.30	-0.03	-0.66	0.13	0.37	-0.01	0.47	0.19	-0.61	0.79*				
	P	-0.19	0.07	0.03	-0.04	-0.32	0.04	0.07	-0.18	0.17	0.17	-0.36	0.66				
Soluble solid concentration	G	0.30	0.50	0.44	0.57	-0.19	0.35	0.50	-0.27	0.35	0.43	-0.01	0.77*	0.93**			
	P	0.24	0.46	0.42	0.52	-0.16	0.32	0.46	-0.19	0.33	0.37	-0.03	0.52	0.51			
Protein content	G	-0.28	-0.22	-0.11	-0.69	-0.09	-0.19	-0.22	0.19	0.14	-0.07	-0.43	-0.26	-0.44	-0.89**		
	P	-0.20	-0.15	-0.11	-0.55	-0.04	-0.16	-0.15	0.13	0.07	-0.09	-0.19	-0.33	-0.34	-0.73		
Sugar content	G	-0.33	-0.61	-0.75*	-0.81*	-0.40	-0.37	-0.62	0.53	-0.56	-0.50	-0.20	-0.33	0.26	-0.30	0.32	
	P	-0.34	-0.55	-0.66	-0.70	-0.34	-0.34	-0.55	0.49	-0.49	-0.46	-0.18	-0.25	0.11	-0.30	0.24	
Starch content	G	0.50	0.59	0.60	0.85*	0.21	0.50	0.60	-0.27	0.24	0.38	0.43	0.35	0.11	0.76*	-0.87**	-0.79*
	P	0.31	0.47	0.43	0.62	0.11	0.44	0.47	-0.23	0.19	0.39	0.36	0.34	0.20	0.65	-0.65	-0.74

G: genetic correlation coefficient, P: phenotypic correlation cofficient.,** Significant at 5% and 1% probability level, respectively.

Conclusions

The selection of hybrids for sources of favorable alleles in a breeding program for sweet corn improvement will depend on the consistency of a cultivar's performance over environments. Our replicated study in two years with seven hybrids was conducted to provide information concerning the effect of environmental factors on the performance of these hybrids. It can be conclude that sugar content, soluble solid concentration (for both years) and number of leaves per plant (in 2009) revealed the highest GCV and PCV values.

Sugar content, soluble solid concentration (for both years) and starch content (in 2010) showed high heritability with high genetic advance. These characters can be improved efficiently by individual selection or breeding strategies in the examined populations. Positive correlations were found between yield (husked, dehusked and fresh kernel) and yield components except 1000 seed weight. Husked ear weight and dehusked ear weight (for both years) could be used as the main criteria for all three types of yield improvement when selecting in the studied materials.

Significant negative correlations between kernel quality and yield and yield related traits, suggests that it should be unfeasible to develop sweet corn varieties with satisfactory yield potential and kernel quality for the different sweet corn markets.

Acknowledgement

The authors thanks Eskişehir Osmangazi University, The Scientific Research Projects Commission for supporting this study as the project number 200823026.

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