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Adaptation of Some Corn Genotypes from Different Variety Groups to Erzurum Plain Conditions

Farklı Çeşit Gruplarına ait Bazı Mısır Genotiplerinin Erzurum Ovası Koşullarına Adaptasyonu

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ABSTRACT

Selection of variety with high potential yield and adaptability is one of the most effective ways to increase corn production. This research was carried out according to the randomized complete blocks experimental design with 10 corn genotypes (five sweet corn, four flint corn, and one dent corn) in 2022 and 2023 years under Erzurum conditions. The differences among the genotypes were significant in terms of all the characteristics investigated, except plant number per hectare. As average of years, the days to silking of the genotypes was between 63.3-78.0 days, days to maturity for fresh ear harvest 98.2-110.0 days, plant number per hectare 86969-89585, ear number per plant 1.10-1.83, chlorophyll value (SPAD unit) 45.2-55.6, maximum quantum yield at PSII (Fv/Fm) 0.716-0.784, green mass yield 75337-108544 kg/ha, kernel number per ear 231.9-692.0, fresh ear yield 15312-25465 kg/ha, grain protein content 10.4-16.2 %. The highest green mass yield was obtained from Simpatico-KWS, the highest fresh ear yield from Khan F_1, the highest kernel protein content from Challenger F_1 and Karaçam genotypes. Only silage or corn for fresh consumption can be produced in Erzurum Plain conditions due to the short vegetation period and low average temperatures. Crow damage during the germination-emergence period and the first frost in autumn may a risk for corn production.

Keywords: Dent corn, Protein, Flint corn, Sweet corn, Yield

ÖZ

Potansiyel verimi ve adaptasyon kabiliyeti yüksek çeşit seçimi mısır üretimini artırmanın en etkili yollarından biridir. Erzurum koşullarında 2022 ve 2023 yıllarında şansa bağlı tam bloklar deneme planına göre yürütülen bu araştırmada 10 mısır genotipi (beş tatlı mısır, dört sert mısır, bir atdişi mısır) kullanılmıştır. Dekara bitki sayısı dışında, incelenen karakterler bakımından genotipler arasında önemli farklar belirlenmiştir. Yılların ortalaması olarak genotiplerin koçan püskülü çıkış süreleri 63,3-78,0 gün, taze koçan hasadı için olum süreleri 98,2-110,0 gün, dekara bitki sayıları 8696,9-8958,5, bitkide koçan sayıları 1,10-1,83, SPAD klorofil değerleri 45,2-55,6, PSII maksimum enerji verimleri (Fv/Fm) 0,716-0,784, hasıl verimleri 7533,7-10854,4 kg/da, koçandaki tane sayıları 231,9-692,0, taze koçan verimleri 1531,2-2546,5 kg/da, tane protein oranları ise %10,4-16,2 arasında değişmiştir. En yüksek hasıl verimi Simpatico-KWS, en yüksek taze koçan verimi Khan F_1, en yüksek tane protein oranı ise Challenger F1 ve Karaçam genotiplerinden elde edilmiştir. Erzurum Ovası koşullarında vejetasyon süresinin kısa ve ortalama sıcaklıkların düşük olması nedeniyle sadece silajlık veya taze tüketim amaçlı mısır üretilebilir. Çimlenme-çıkış dönemindeki karga zararı ve sonbahardaki ilk donlar mısır üretimi için risk oluşturabilir.

Anahtar Kelimeler: Atdişi mısır, Protein, Sert mısır, Tatlı mısır, Verim

Introduction

Corn is a multi-purpose crop that is widely used in animal nutrition, human nutrition and industry. Worldwide, it ranks second after wheat with a cultivation area of 208 234 140 ha among cultivated plants, its production is 1 241 557 811 tons, and its kernel yield is 5960 kg/ha. Corn, which ranks third after wheat and barley with a cultivation area of 958 017 ha in Türkiye, has a production of 9 000 000 tons and a grain yield of 9390 kg/ha (Anonymous, 2023a). The cultivation area of corn in Erzurum province is 150 ha and its yield is 1970 kg/ha (Anonymous, 2024). In the world, 61% of the corn produced is used as animal feed, 19% as industrial raw material, 15% as direct human food, 4% as losses, and 1% as seed (Garcia-Lara & Sena-Saldivar, 2019). When the latest data are compared with the data of the year 2000, the amount of corn production has increased by 210% in the world and 391% in Türkiye (Anonymous, 2023a). Despite that, since the increasing need could not be met, Türkiye imported 3 561 000 tons of corn and products against 1 270 000 tons of exports in the 2021/22 marketing year, and our sufficiency rate is 76.6% (Anonymous, 2023b).

The corn species includes seven different groups of varieties: dent corn, flint corn, sweet corn, popcorn, flour corn, waxy corn and pod corn, which are separated from each other according to their endosperm structure. Dent corn, which is widely used in animal nutrition and industry, meets most of the world's corn production. Flint corn, which is the most used in bread making, ranks second in the production share. Popcorn, which is known for its thick grain pericarp and hard endosperm structure and is generally used as a snack, ranks third in Türkiye in terms of cultivation area. Sweet corn, which ranks fourth in terms of cultivation area, is used in human nutrition as fresh, canned or frozen with higher kernel sugar, protein and vitamin content than other groups (İdikut et al., 2016; Öztürk et al., 2019; Sönmez et al., 2013). In corn, where genetic diversity is very rich, many research has been carried out to determine the rapidly increasing number of varieties with high adaptation and yield in certain ecologies. The first research on the adaptation of corn varieties to Erzurum conditions was carried out by Tosun (1967), the green mass yield was lower in the early varieties and the average of the varieties was determined as 36100 kg/ha, and M-202 variety was recommended for the region. Tosun (1970) determined the plant height as 84.2-173.2 cm, cob length as 9.8-19.4 cm, cob weight as 32.0-115.3 g, number of cobs per hectare between 17500-66620 and the dry straw yield between 3175-6450 kg/ha in 18 sweet corn varieties under Erzurum conditions and he found that Golden Midget and North Starr varieties with early and high cob number promising. Ergin (1974) investigated the effect of plant density (50000, 60000, 75000, 100000 plants/ha), nitrogen (0, 90, 180, 270 kg/ha) and phosphorus (0, 70, 140 kg/ha) doses on M-202 corn variety under Erzurum conditions, and the highest grain and green mass yields obtained from 100000 plants/ha, 270 kg N/ha and 70 kg P/ha treatments. Öztürk and Akkaya (1996) conducted a study with 25 corn varieties and suggested early and relatively high-yielding Inra 260 and Inra 380 varieties as silage for Erzurum Plain conditions. Bulut et al. (2008) examined the adaptation of 17 corn varieties to Erzurum conditions, the green mass yields of the varieties ranged between 61035-65500 kg/ha, dry matter yields ranged between 13763-17744 kg/ha, crude protein yield ranged between 905-996 kg/ha, and DK-440 and DK-585 varieties were recommended as silage. Öztürk et al. (2008) investigated the effect of plant density (83000, 91000, 100000, 125000, 143000 plants/ha) on silage production in DK-440 and DKC-4604 corn varieties and determined the ideal density as 125000 plants/ha in Erzurum.

In recent years, the cultivation area and economic value of sweet corn have been increasing. Sweet corn varieties have high yield potential and can also be grown in environments with limited vegetation periods, such as Erzurum, due to their short maturity period. The remaining parts after the cob harvest are also a valuable crop and silage material (Arslan & Williams, 2015). In the research carried out with 11 sweet corn varieties in Erzurum conditions, marketable ear yield according to varieties was 3205-16858 kg/ha, fresh kernel yield was 2412-11855 kg/ha, kernel protein ratio was 11.3-16.5%, and green mass yield was 35458-49406 kg/ha, and Signet F_1 and Challenger F_1 varieties were recommended for the region (Stansluos et al., 2020a). Local corn populations are valuable as a potential gene source in breeding programs for possible new needs in the feed and food industry, especially changes in environmental factors (Drinic et al., 2012). For this reason, emphasis is placed on collecting, identifying, and protecting local populations. In a study conducted on 196 local genotypes belonging to the Black Sea Region, 84 of the genotypes were found to belong to the flint corn, 64 dent corn, and 48 popcorn groups, plant grain yield was determined between 16.99-197.73 g, grain oil content was 2.22-6.41%, grain protein content was 8.88-16.42%, and local genotypes were defined as a rich gene source (Öner, 2011). In the research carried out with 18 local corn populations and two registered varieties of Trabzon province, the grain yield was determined between 3193-11671 kg/ha, and grain protein content varied between 9.89-14.50%, and the highest protein contents were determined in Köprübaşı, Çaykara and Tonya landraces (Öztürk & Büyükgöz, 2021).

In order to meet the increasing demand for corn in different variety groups, such as dry grain, fresh kernel or silage purposes, it is necessary to develop varieties with high adaptability, yield and nutritional value as well as to expand their production. The conditions of Erzurum Plain, where the altitude is high, the vegetation period is short and the average temperature is low, make corn production for grain purposes risky, and allow corn cultivation for silage or fresh consumption by using early varieties. In this study, the adaptation of a total of 10 corn genotypes, including five sweet corn varieties, one dent corn, and four flint corn landraces to the conditions of Erzurum Plain was examined.

Methods

Materials

This research was carried out in 2022 and 2023 years at Erzurum, Atatürk University Plant Production Application and Research Center trial area. The 10 corn genotypes, some traits of which are presented in Table 1, were used as plant material, ammonium sulfate, triple superphosphate and potassium sulfate were used as fertilizer sources, groundwater and drip irrigation system were used.

During the growing period, less rainfall fell in 2022 and more in 2023 compared to the long-term average (Table 2). During the trial years, June received more rainfall than in long-term average, and August and September received less rainfall. In both years, the average temperatures in May, June and July were lower than in long-term average, and the average temperature in August was higher. Physical and chemical analyses of samples taken from 0-30 cm depth of the experimental area soil were carried out according to the methods described by Dane and Topp (2018) and Sparks et al. (2020). It was determined that the soils had clay-loam textured in

Table 1
Some traits of the corn genotypes used in the research

Genotypes	Company / Origin	Traits
Argos F_1	Semillas Fito Tarım	Sweet corn, super-sweet, maturity period 80-90 days, kernel color is yellowish golden
Baron F_1	May Tohum	Sweet corn, super-sweet, very early, plant height 190-195 cm, kernel color is dark yellow
Challenger F_1	BAYER-Seminis	Sweet corn, super-sweet, maturity period 80-85 days, plant height 170-180 cm, kernel color is yellow
Khan F_1	May Tohum	Sweet corn, super-sweet, early, plant height 190-200 cm, kernel color is dark yellow
Signet F_1	Monsanto Gıda ve Tarım	Sweet corn, sugary enhanced, maturity period 60–65 days, plant height 150–160 cm, kernel color is yellow
Simpatico-KWS	KWS Türk Tarım Ticaret	Dent corn, FAO 400 grub, for silage, early and with high silage yield, ear rate and quality
Taşören landrace	Çaykara-Taşören village	Flint corn, kernel color is yellow, cultivation altitude is 815 m
Karaçam landrace	Çaykara-Karaçam village	Flint corn, kernel color is yellow, cultivation altitude is 1350 m
Ormanüstü landrace	Maçka-Ormanüstü village	Flint corn, kernel color is yellow, cultivation altitude is 1000 m
Sayraç landrace	Tonya-Sayraç village	Flint corn, kernel color is yellow, cultivation altitude is 950 m

Table 2
Some climate data of the research area during 2022 and 2023 with the long-term mean (LTM: 1990-2021)[1]

Months	Total rainfall (mm)			Average temperature (°C)			Average relative humidity (%)			Maximum temperature (°C)		Minimum temperature (°C)	
	2022	2023	LTM	2022	2023	LTM	2022	2023	LTM	2022	2023	2022	2023
May	89.3	97.0	90.4	9.1	10.4	11.6	67.3	64.3	59.8	24.1	22.5	-3.8	-4.1
June	80.4	63.0	39.8	15.9	14.8	16.2	62.8	66.5	53.7	29.2	25.9	2.5	2.0
July	5.2	55.6	24.2	19.4	18.2	20.3	48.1	57.0	46.5	34.2	31.8	3.1	4.0
August	0.0	4.4	26.3	21.9	21.3	20.8	36.2	42.1	44.7	33.7	36.2	1.6	6.4
September	8.8	3.3	26.4	15.5	16.4	15.9	42.6	46.3	47.9	32.3	31.0	-3.5	1.9
Total	183.7	223.3	207.1										
Mean				16.4	16.2	17.0	51.4	55.2	50.5				

[1]Taken from the annual climate observations of Erzurum Meteorology Regional Directorate

both years, aggregate stability value was between 25.1-27.5%, slightly saline (EC: 0.16-0.19 ds/m), less calcareous (1.05-1.37%), slightly alkaline reaction (pH: 7.54-8.13), organic matter content (1.63-2.09%) and available phosphorus amount (28.0-34.8 kg/ha) were low, and available potassium amount (819-981 kg/ha) was high (Taşova & Akın, 2013).

Methods

The first tillage was done in fall, the seedbed was prepared with cultivator + rake cultivation in spring, and the sowing was carried out manually and by quarry on May 16, 2022, and June 3, 2023. In this research, which was carried out in 3 replications according to randomized complete block design, each plot consisted of five rows of plants with a length of 5.0 m. Two seeds were planted at a depth of 3-4 cm using a row marker, with a row spacing of 50 cm and an intra-row of 20 cm (targeted density 100000 plants/ha), and the seeds were covered with soil. When the emerging seedlings had 3-4 leaves, thinning was done so that one seedling remained in each hill, and the first weeding were done manually by hoe. The plots were fertilized at 200 kg N/ha, 100 kg P_2O_5/ha and 150 kg K_2O/ha in order to minimize the limiting effects of NPK deficiency. 40% of the nitrogen and all of the phosphorus and potassium were sprinkled in the plots before sowing and mixed with the soil, while the remaining part of the nitrogen was sprinkled in rows when the plants were about 40 cm height the throat was filled. Soil moisture content was monitored by gravimetric method, and 493 mm of water was applied to each plot in equal amounts during the growing period in 2022 and 361 mm in 2023. Depending on the variety, the plants were harvested between August 22 and September 3 in 2022, and between September 10 and September 22 in 2023. In determining the harvest time, the recommended kernel moisture content for sweet corn was based on the date when it decreased to 73±1% (Okumura et al., 2013), two rows edge effects were left from the side rows and row ends of the plots, the plants in the remaining 6.3 m^2 area were harvested with a sickle from a 10 cm height from the soil surface, and the yield was determined by weighing immediately. The edge effect plants were used to check whether kernels reached grain harvest maturity.

In each plot, the number of days from sowing date to the date of 50% silking and maturity (kernel moisture content 73% ±1%) was determined. Plant density was calculated at the harvesting time by counting the plants (excluding tillers) in the harvesting area. Randomly, 10 plants were chosen to measure the plant height from the soil surface to the tip of the tassel, first ear height from the soil surface to the node where the first ear emerged, and the number of leaves per plant by counting the leaves with at least 50% green leaf blade. During silking period, chlorophyll value (SPAD unit) was measured by averaging the readings made with a chlorophyll meter (Model SPAD 502, Minolta, Japan) at the bottom, middle and the tip of the leaf blade at the node where the first ear emerged, and the maximum quantum yield at PSII (Fv/Fm) was measured by averaging the measurements made with the portable chlorophyll fluorescence system (Handy Pea, Hansatech Instruments Kink's Lynn, UK) on the same leaf blades and in the same parts (Guo et al., 2021). Immediately after harvest, all the ears were separated from the husks and those holding at least 50% of the kernels were counted, the value obtained was divided by the number of plants within the harvesting area and the number of ear per plant was calculated. The ears were weighed, and the yield of fresh de-husked ear was determined. Randomly, 10 ears were selected, the ear diameter was measured from the middle part using an electronic caliper, and the ear length was measured from the place where the lowest kernel at the bottom to the place where the end kernel at tip. The number of kernel rows and the number of kernels per row were determined from the same ears, and the number of kernels per ear was calculated from the two values. The grain protein content was determined by the Kjeldahl method using the multiplication factor of % N × 6.25 in fresh kernel samples (Okumura et al., 2014). Variance analysis of the data was performed with the RStudio (2020) statistical analysis program, and the differences between the means were compared using Duncan multiple comparison test.

Results and Discussion

In both trial years, due to crow damage during the germination and emergence periods, a full seedling establishment could not be achieved, and the targeted plant density could not be reached in any of the plots. Aphid pests were observed in the plants in two years, and there was no plant loss due to lodging or breakage. The first frosts occurred on September 10, 2022 (-1.1˚C) and October 18, 2023 (-0.9˚C). In the first year, in all genotypes, edge-effect plants that were still at the beginning of the physiological maturity period died due to the first frost. In the second year, it was observed that the edge effect plants reached physiological maturity (the husks turned yellow and a black layer was formed where the kernel was attached to the ear) in all genotypes.

Significant differences were determined among corn genotypes in terms of the traits examined, except for the number of plants per hectare (Tables 3-5). Year effect was insignificant for maturity period, number of leaves per plant, chlorophyll value, maximum quantum at PSII, ear diameter and grain protein content, but significant for other traits. The fact that the temperatures of June, July and August were more favorable for corn in 2022 shortened the silking

Table 3
Mean values of corn genotypes for days to silking, days to maturity, plant height, first ear height and leaf number per plant[1]

	Days to silking (day)	Days to maturity (day)	Plant height (cm)	First ear height cm)	Leaf number per plant
Year (Y)					
2022	68.9[b]	106.1	233.1[a]	83.7[a]	10.9
2023	71.8[a]	106.0	222.8[b]	71.2[b]	11.2
Mean	70.6	106.0	227.9	77.5	11.0
Genotype (G)					
Argos F_1	71.3[c]	106.7[bcd]	203.2[d]	59.4[d]	11.6[b]
Baron F_1	70.0[c]	107.2[bc]	201.1[de]	69.0[c]	11.1[bc]
Challenger F_1	72.2[c]	106.8[bcd]	199.5[de]	55.2[de]	11.4[bc]
Khan F_1	78.0[a]	110.0[a]	206.3[d]	62.7[cd]	10.7[bcd]
Signet F_1	66.3[d]	98.2[f]	189.5[e]	50.8[e]	9.6[e]
Simpatico-KWS	71.7[c]	106.2[cde]	267.4[a]	102.5[b]	14.8[a]
Çaykara-Taşören	74.8[b]	107.8[abc]	274.7[a]	119.3[a]	11.3[bc]
Çaykara-Karaçam	71.7[c]	108.8[ab]	268.8[a]	103.5[b]	10.5[cd]
Maçka-Ormanüstü	63.3[e]	104.0[e]	220.7[c]	49.9[e]	9.2[e]
Tonya-Sayraç	66.7[d]	104.5[de]	248.3[b]	102.3[b]	10.1[de]
Interaction (G × Y)					
Argos F_1 × Y1	68.3[g-j]	106.7	209.2[c-f]	62.9[gh]	10.8[d-g]
Argos F_1 × Y2	74.3[cd]	106.7	197.1[efg]	55.9[ghi]	12.3[c]
Baron F_1 × Y1	69.7[f-i]	107.7	201.3[d-g]	75.3[ef]	11.3[cde]
Baron F_1 × Y2	70.3[e-h]	106.7	200.9[d-g]	62.7[gh]	10.9[c-f]
Challenger F_1 × Y1	69.7[f-i]	106.7	200.7[d-g]	57.2[ghi]	11.1[cde]
Challenger F_1 × Y2	74.7[bcd]	107.0	198.3[efg]	53.2[ghi]	11.6[cde]
Khan F_1 × Y1	77.3[abc]	109.7	211.0[cde]	64.8[fg]	11.1[cde]
Khan F_1 × Y2	78.7[a]	110.3	201.5[d-g]	60.6[gh]	10.3[e-i]
Signet F_1 × Y1	65.7[jkl]	98.7	190.2[fg]	56.8[ghi]	9.7[f-i]
Signet F_1 × Y2	67.0[hij]	97.7	188.8[g]	44.7[i]	9.5[ghi]
Simpatico-KWS × Y1	71.3[d-g]	105.7	283.5[a]	109.2[c]	15.9[a]
Simpatico-KWS × Y2	72.0[def]	106.7	251.3[b]	95.7[d]	13.7[b]
Çaykara-Taşören × Y1	72.0[def]	108.0	276.3[a]	113.0[bc]	10.7[d-h]
Çaykara-Taşören × Y2	77.7[ab]	107.7	273.0[a]	125.7[a]	11.8[cd]
Çaykara-Karaçam × Y1	70.0[e-h]	109.0	287.0[a]	124.1[ab]	9.3[hi]
Çaykara-Karaçam × Y2	73.3[de]	108.7	250.7[b]	83.0[e]	11.7[cd]
Maçka-Ormanüstü × Y1	63.0[l]	104.3	223.2[c]	51.8[hi]	9.0[i]
Maçka-Ormanüstü × Y2	63.7[kl]	103.7	218.1[cd]	48.0[i]	9.4[hi]
Tonya-Sayraç × Y1	67.0[hij]	104.3	248.2[b]	122.0[ab]	9.7[f-i]
Tonya-Sayraç × Y2	66.3[ijk]	104.7	248.4[b]	82.7[e]	10.4[d-h]
Sources of variation			*F* values[2]		
Year (Y)	26.64***	0.04	15.55***	53.44***	2.85
Genotype (G)	33.88***	64.75***	65.51***	95.06***	27.45***
G x Y	2.67*	0.20	2.60*	9.18***	4.75***
CV (%)	2.55	1.78	4.42	8.55	6.59

[1] The means marked with the same letter are not different from each other.
[2] *F* values marked with * and *** are significant at the probability level of 0.05 and 0.001, respectively.

Table 4
Mean values of corn genotypes for ear number per plant, chlorophyll value, PSII maximum energy yield, plant number per hectare and green mass yield[1]

	Ear number per plant	Chlorophyll value (SPAD unit)	PSII maximum energy yield (Fv/Fm)	Plant number per hectare	Green mass yield (kg/ha)
Year (Y)					
2022	1.50[a]	51.2	0.763	89,058[a]	87,462[a]
2023	1.39[b]	52.6	0.760	86,578[b]	82,883[b]
Mean	1.45	51.9	0.761	87,818	85,173
Genotype (G)					
Argos F_1	1.10[c]	52.5[a]	0.778[ab]	87,674	78,383[ef]
Baron F_1	1.10[c]	53.6[a]	0.716[d]	88,237	91,350[b]
Challenger F_1	1.12[c]	54.6[a]	0.773[abc]	87,156	81,844[de]
Khan F_1	1.13[c]	55.6[a]	0.758[bc]	88,060	81,870[de]
Signet F_1	1.39[b]	45.2[b]	0.783[a]	87,058	76,314[f]
Simpatico-KWS	1.78[a]	53.7[a]	0.757[c]	87,586	108,544[a]
Çaykara-Taşören	1.67[a]	47.3[b]	0.778[ab]	87,112	87,233[bc]
Çaykara-Karaçam	1.67[a]	51.7[a]	0.725[d]	89,585	87,125[bc]
Maçka-Ormanüstü	1.70[a]	53.1[a]	0.784[a]	86,969	75,337[f]
Tonya-Sayraç	1.83[a]	51.7[a]	0.757[d]	88,747	83,726[cd]
Interaction (G × Y)					
Argos F_1 × Y1	1.20	53.2	0.780[ab]	89,570	82,532
Argos F_1 × Y2	1.00	53.0	0.776[abc]	85,777	74,233
Baron F_1 × Y1	1.17	53.4	0.724[ef]	88,475	91,882
Baron F_1 × Y2	1.03	53.9	0.712[f]	88,000	90,820
Challenger F_1 × Y1	1.20	54.7	0.789[a]	90,311	86,747
Challenger F_1 × Y2	1.03	54.4	0.757[bcd]	84,000	76,939
Khan F_1 × Y1	1.17	55.9	0.781[ab]	88,564	83,206
Khan F_1 × Y2	1.10	55.4	0.736[def]	87,556	80,534
Signet F_1 × Y1	1.51	44.5	0.788[ab]	88,782	80,052
Signet F_1 × Y2	1.27	46.0	0.779[abc]	85,333	72,577
Simpatico-KWS × Y1	1.69	52.5	0.749[cde]	89,837	111,616
Simpatico-KWS × Y2	1.87	54.9	0.765[abc]	85,333	105,472
Çaykara-Taşören × Y1	1.70	44.6	0.790[a]	88,889	89,942
Çaykara-Taşören × Y2	1.63	50.0	0.766[abc]	85,333	84,523
Çaykara-Karaçam × Y1	1.73	51.3	0.729[def]	89,837	87,636
Çaykara-Karaçam × Y2	1.60	52.1	0.721[ef]	89,333	86,614
Maçka-Ormanüstü × Y1	1.77	52.4	0.775[abc]	88,160	77,276
Maçka-Ormanüstü × Y2	1.63	53.8	0.794[a]	85,777	73,398
Tonya-Sayraç × Y1	1.89	49.5	0.721[ef]	88,160	83,735
Tonya-Sayraç × Y2	1.77	54.0	0.793[a]	89,333	83,718
Sources of variation			*F* values[2]		
Year (Y)	7.35*	3.41	0.48	7.26*	21.99***
Genotype (G)	24.02***	6.99***	12.94***	0.34	39.05***
G x Y	0.82	0.78	6.22***	0.79	1.20
CV (%)	10.72	5.80	2.11	4.06	4.44

[1] The means marked with the same letter are not different from each other.
[2] *F* values marked with * and *** are significant at the probability level of 0.05 and 0.001, respectively.

Table 5

Mean values of corn genotypes for ear length, ear diameter, kernel number per ear, fresh ear yield, and grain protein content[1]

	Ear length (cm)	Ear diameter (mm)	Kernel number per ear	Fresh ear yield (kg/ha)	Grain protein content (%)
Year (Y)					
2022	17.1^{b}	47.1	475.3^{b}	22,274^{a}	13.9
2023	17.7^{a}	47.0	508.4^{a}	20,215^{b}	14.2
Mean	17.4	47.0	491.8	21,245	14.1
Genotype (G)					
Argos F_1	20.9^{ab}	47.7^{c}	692.0^{a}	24,712^{b}	15.9^{a}
Baron F_1	16.5^{d}	50.6^{a}	678.9^{a}	23,710^{a}	10.9^{e}
Challenger F_1	20.5^{b}	48.0^{bc}	678.3^{a}	24,577^{a}	16.2^{a}
Khan F_1	21.5^{a}	49.1^{abc}	675.5^{a}	25,465^{a}	14.5^{c}
Signet F_1	18.1^{c}	48.0^{bc}	591.7^{b}	23,318^{a}	12.7^{d}
Simpatico-KWS	18.3^{c}	50.5^{a}	628.9^{b}	25,195^{a}	10.4^{e}
Çaykara-Taşören	13.1^{f}	41.7^{d}	232.7^{c}	16,252^{b}	15.1^{bc}
Çaykara-Karaçam	16.0^{de}	50.2^{ab}	272.3^{c}	16,315^{b}	16.2^{a}
Maçka-Ormanüstü	13.6^{f}	42.7^{d}	236.3^{c}	15,312^{b}	15.7^{ab}
Tonya-Sayraç	15.4^{e}	41.6^{d}	231.9^{c}	17,591^{b}	13.0^{d}
Interaction (G × Y)					
Argos F_1 × Y1	18.9^{ef}	46.7^{cd}	678.8	26,083	15.6
Argos F_1 × Y2	22.8^{a}	48.7^{abc}	705.2	23,340	16.2
Baron F_1 × Y1	16.6^{gh}	51.3^{a}	640.7	24,061	10.9
Baron F_1 × Y2	16.3^{gh}	49.8^{abc}	717.1	23,358	10.9
Challenger F_1 × Y1	19.8^{de}	46.7^{cd}	637.1	26,077	16.0
Challenger F_1 × Y2	21.2^{bc}	49.3^{abc}	719.4	23,078	16.4
Khan F_1 × Y1	20.9^{cd}	47.0^{bcd}	633.1	26,400	14.1
Khan F_1 × Y2	22.2^{ab}	51.2^{a}	717.9	24,530	14.9
Signet F_1 × Y1	17.9^{f}	47.9^{a-d}	600.4	25,385	13.1
Signet F_1 × Y2	18.3^{f}	48.2^{a-d}	583.0	21,253	12.3
Simpatico-KWS × Y1	18.1^{f}	50.7^{ab}	622.9	25,571	10.6
Simpatico-KWS × Y2	18.4^{f}	50.4^{abc}	634.9	24,818	10.1
Çaykara-Taşören × Y1	13.1^{i}	41.7^{ef}	223.5	16,538	14.8
Çaykara-Taşören × Y2	13.1^{i}	41.7^{ef}	242.0	15,964	15.4
Çaykara-Karaçam × Y1	16.2^{gh}	50.9^{a}	276.7	16,907	16.0
Çaykara-Karaçam × Y2	15.8^{gh}	49.5^{abc}	267.9	15,725	16.3
Maçka-Ormanüstü × Y1	13.8^{i}	44.9^{de}	218.9	15,293	15.4
Maçka-Ormanüstü × Y2	13.5^{i}	40.6^{f}	253.7	15,331	15.9
Tonya-Sayraç × Y1	15.6^{gh}	42.8^{ef}	220.5	20,429	12.9
Tonya-Sayraç × Y2	15.2^{h}	40.3^{f}	243.2	14,754	13.2
Sources of variation			*F* values[2]		
Year (Y)	11.64**	0.04	14.38***	17.36***	2.34
Genotype (G)	118.45***	21.14***	244.19***	29.97***	100.31***
G x Y	5.95***	2.61*	1.75	1.35	1.41
CV (%)	3.85	2.11	6.89	9.01	3.79

[1] The means marked with the same letter are not different from each other.

[2] *F* values marked with *, ** and *** are significant at the probability level of 0.05, 0.01 and 0.001, respectively.

period, increased plant height, first ear height and ear number per plant. In the second year, the greater crow damage reduced the number of plants, and accordingly, lower green-mass and fresh ear yields were obtained. The reactions of genotypes to environmental factors were different in terms of silking days, plant height, first ear height, number of leaves per plant, maximum quantum yield at PSII, ear length and ear diameter, and "genotype × year" interactions were significant.

Days to Silking and Days to Maturity

Days to silking of maize genotypes ranged between 63.0-77.3 days in 2022 and 63.7-78.7 days in 2023. In two years, the Ormanüstü landrace was the earliest in terms of days to silking and the Khan F_1 variety the latest, however, the "genotype × year" interaction was significant due to the different responses of other genotypes to environmental factors (Table 3). Days to silking may vary according to growing techniques such as genetic structure, environmental factors and sowing date. Days to silking was between 69.8-74.4 days in Eskişehir conditions in sweet corn genotypes (Sönmez et al., 2013), 76.17-90.67 days in Erzurum conditions (Stansluos et al., 2020a). It was determined between 57-85 days in Samsun conditions (Öner, 2011) and 52.7-66.5 days in Trabzon conditions (Öztürk & Büyükgöz, 2021) in local corn genotypes. In this study, the relationships between days to silking and days to maturity (r=0.69), number of leaves per plant (r=0.45) and ear length (r=0.47) were positive and significant (Table 6). The mean days to maturity of genotypes ranged from 98.2 days to 110.0 days. The shortest maturity period was observed in Signet F_1 variety, followed by the Ormanüstü and Sayraç landraces. Khan F_1 and Karaçam genotypes were the latest to reach maturity for fresh ear. Significant differences among maize genotypes in terms of days to maturity were also observed in previous studies, ranging between 105.7-120.2 days in Erzurum conditions (Stansluos et al., 2020a), 82.5-106.5 days in Slovakia conditions (Baratova et al., 2016), and 83.0-87.0 days in İzmir conditions (Kantarcı et al., 2016). The relationship between days to maturity and SPAD value was found to be positive and significant (r=0.58).

Plant Height and First Ear Height

In 2022 and 2023, the plant heights of the corn genotypes ranged between 190.2-287.0 cm and 188.8-273.0 cm, and the first ear height ranged between 51.8-124.1 cm and 44.7-125.7 cm, respectively (Table 3). The shortest plant height was measured in Signet F_1 variety in the two years, and the longest plant height was measured in Karaçam landrace in 2022 and Taşören landrace in 2023 year. The shortest first ear height was determined in Ormanüstü and Signet F_1 genotypes, and the tallest in Karaçam and Taşören landraces. Generally, landraces had taller plant height and first ear height, followed by the Simpatico-KWS variety, and sweet corn varieties taking the last ranks. Plant height and first ear height can vary significantly according to genetic structure, environmental factors, and cultivation techniques (Arteaga et al., 2016; Beyene et al., 2005). Previous research has also shown that sweet corn (Sönmez et al., 2013; Stansluos et al., 2020a) and local maize (Öner, 2011; Öztürk & Büyükgöz, 2021) genotypes were found to be significantly different in terms of plant height and first ear height. The first ear height was also higher in genotypes with long plant height. It was determined that plant height was positively correlated with first ear height (r=0.90), ear number per plant (r=0.76), green mass yield (r=0.56) and negatively correlated with fresh ear yield (r=-0.50), ear length (r=-0.55) and kernel number per ear (r=-0.63). Similar to plant height, the first ear height is also positively correlated with the ear number per plant (r=0.63), green mass yield (r=0.56) and negatively correlated with ear length (r=-0.44) and kernel number per ear (r=-0.50) (Table 6).

Number of Leaf per Plant and Number of Ear per Plant

As an average of the years, the number of leaves of the genotypes per plant varied between 9.2 and 14.8, and the number of leaves was the least in the Ormanüstü landrace and the highest in Simpatico-KWS variety in two years. However, the order of other genotypes in terms of the number of leaves differed according to the years and the interaction of "genotype × year" was found to be important (Table 3). The ear number per plant varied between 1.10 and 1.83. The Sayraç landrace had the highest ear number per plant, followed by the Simpatico-KWS variety. The lowest number of ear per plant was determined in Agros F_1 and Baron F_1 sweet corn varieties (Table 4). Due to their different responses to genetic makeup and environmental factors, significant differences can be seen between maize genotypes in terms of the number of leaves and cobs per plant. The number of leaves per plant was related to light retention, photosynthesis rate, and yield (Li et al., 2016), while the number of leaves in this study was similar to that of sweet corn (Sönmez et al., 2013; Stansluos et al., 2020a) and local maize (Öner, 2017; Öztürk & Büyükgöz, 2021) are close to the previously reported values for genotypes. In this study, a positive and significant (r=0.75) relationship was determined between the number of leaves and green mass yield. Maize genotypes with a higher number of leaves are more suitable for silage (Subedi & Ma, 2005) and the Simpatico-KWS variety for silage has attracted attention with this feature.

Although hybrid corn varieties usually have a well-developed ear per plant, high ear counts have been detected in Simpatico-KWS and Signet F_1 varieties. In this study, the ear number per plant determined in sweet corn

Table 4
Correlation coefficients among the traits investigated of the corn genotypes (n=20)

	SD[1]	MD	PH	FEH	LNPP	ENPP	SPAD	Fv/Fm	PNPD	GMY	EL	ED	KNPE	FEY
MD	0.69***	-												
PH	0.10	0.32	-											
FEH	0.22	0.34	0.90***	-										
LNPP	0.45*	0.29	0.31	0.28	-									
ENPP	-0.40	-0.17	.76***	0.63**	-0.01	-								
SPAD	0.29	0.58**	-0.16	-0.24	0.29	-0.31	-							
Fv/Fm	-0.25	-0.38	-0.16	-0.34	-0.12	0.07	-0.18	-						
PNPD	-0.22	0.19	0.26	0.23	-0.04	0.18	-0.03	-0.11	-					
GMY	0.18	0.31	0.56**	0.56**	0.75***	0.34	0.15	-0.32	0.34	-				
EL	0.47*	0.16	-0.55**	-0.44*	0.28	-0.70***	0.40	0.00	-0.14	-0.09	-			
ED	0.34	0.21	-0.24	-0.16	0.37	-0.45*	0.25	-0.54**	0.04	0.34	0.61**	-		
KNPE	0.35	0.05	-0.63**	-0.50*	0.39	-0.78***	0.34	-0.07	-0.15	0.12	0.84***	0.69***	-	
FEY	0.05	0.03	-0.50*	-0.30	0.40	-0.58**	0.25	-0.05	0.06	0.27	0.78***	0.60**	0.91***	-
GPC	0.15	0.26	-0.04	-0.16	-0.38	-0.15	0.06	0.27	-0.03	-0.63**	0.05	-0.28	-0.28	-0.36

[1] SD: silking days; MD: maturity days; PH: plant height; FEH: first ear height; LNPP: leaf number per plant; ENPP: ear number per plant; SPAD: chlorophyll value; Fv/Fm: PSII maximum energy yield; PNPD: plant number per hectare; GMY: green mass yield; EL: ear length; ED: ear diameter; KNPE: kernel number per ear; FEY: fresh ear yield; GPC: grain protein content. Correlation coefficients marked with *, ** and *** are significant at the probability level of 0.05, 0.01 and 0.001, respectively.

varieties is close to the values determined by Eşiyok and Bozokalfa (2005) between 1.10-1.14 and lower than the values determined by Sönmez et al. (2013) between 1.56-1.96. The number of ear per plants belonging to local populations is close to the results of Öner (2017) and higher than the results of Öztürk & Büyükgöz (2021). It was determined that the number of ear per plant was negatively and significantly related to fresh ear yield (r=-0.58), ear length (r=-0.70), ear diameter (r=-0.45) and number of kernels per ear (r=-0.78).

Chlorophyll Value (SPAD units) and Maximum Quantum Yield at PSII (Fv/Fm)

Chlorophyll values (SPAD unit) of maize genotypes ranged from 45.2 to 55.6. The highest value was measured in the Khan F_1 variety, followed by the Challenger F_1 and Simpatico-KWS varieties. The lowest values were measured in the Signet F_1 and Taşören genotypess, and these genotypes had significantly lower chlorophyll values than the others (Table 4). The measured chlorophyll values were higher than the values reported by Tunalı et al. (2012) as 40.3-46.3 in maize varieties and consistent with the values reported by Wang et al. (2019) between 43.1 and 66.3. Chlorophyll value is one of the main chloroplast elements for photosynthesis, and leaf chlorophyll content is positively correlated with the rate of photosynthesis (Guo et al., 2008). Leitao et al. (2023) pointed out that there is a positive and significant relationship between chlorophyll value and kernel yield in corn. In this study, the correlation coefficients between the SPAD value and the other traits examined were not significant. Wang et al. (2019) identified a very weak and insignificant relationship between chlorophyll value and kernel yield in 55 maize genotypes, similar to our results.

The maximum quantum yield (Fv/Fm) is considered as an indicator of PSII potential quantum activity and as a measure of plant photosynthesis ability (Maxwell & Johnson, 2000) and is normally between 0.75-0.85 (Bolhar-Nordenkampf et al., 1989; Sayar et al., 2008). The Fv/Fm values of the genotypes ranged from 0.721 to 0.790 in 2022 and from 0.712 to 0.794 in 2023, and the genotype × year interaction was significant due to different responses to changing environmental conditions in terms of the Fv/Fm value (Table 4). Simpatico-KWS, Ormanüstü, and Sayraç genotypes had higher Fv/Fm values in 2023, while the other seven genotypes had higher Fv/Fm values in 2022. According to the average of the years, the highest Fv/Fm values were measured in Ormanüstü and Signet F_1, and the lowest Fv/Fm values were measured in Baron F_1 and Karaçam genotypes. In previous studies, significant differences were determined between maize genotypes in terms of maximum energy yield, and relatively high Fv/Fm values were measured according to our findings, between 0.770-0.844 by Özdemir & Sade (2019) and 0.780-0.830 by Badr & Brüggemann (2020). The Fv/Fm value was significantly correlated only with ear diameter (r=-0.54) (Table 6).

Number of Plants per Hectare and Green Mass Yield

The number of plants per hectare is one of the most important determinants of yield, and the ability to reach the target plant density is an important feature for high yields. In this study, the targeted plant density (100000 plants/ha) could not be reached in any genotype, and the plant density decreased significantly in 2023 as plant losses due to crow damage in the germination-emergence period were higher (Table 4). Due to the decrease in kernel starch ratio in sweet corn varieties, the germination and emergence rate may be lower than in dent corn and flint corn varieties (Azanza et al. 1996; Szymanek et al. 2006). However, in this study, the differences between genotypes in terms of the number of plants per hectare at harvesting time were not significant. The number of plants per hectare varied between 86969 and 89585 according to genotypes, and the lowest and highest values were determined in the Ormanüstü and Karaçam landraces, respectively. High yields can be achieved with an establishment of optimum plant number per unit area, their management and protection until harvest (Mathukia et al., 2014). Since the plant density at harvest is also affected by environmental factors, environmental factors should be taken into consideration as well as the biological characteristics of the seed in the calculation of seeding rate.

As average of the varieties, 87462 kg/ha and 82883 kg/ha of green mass yields were obtained in 2022 and 2023 years respectively, and the green mass yield decreased significantly in 2023 due to the decrease in plant density (Table 4). The green mass yield of corn genotypes ranged between 75337-108544 kg/ha, and significant differences were determined between the genotypes. The highest green mass yield was obtained from the Simpatico-KWS variety, followed by the Baron F_1 sweet corn variety. The lowest yields were obtained by Ormanüstü and Signet F_1 genotypes. Since corn is an important silage crop, genotypes that can be used for both food and fodder purposes may be more valuable. Green mass yield can vary according to plant density, fertilization, irrigation and other cultivation techniques, as well as environmental and genetic factors. In this study, green mass yields obtained from sweet corn varieties are considerably higher than those ranging from 21553 to 29093 kg/ha in Karaman conditions (Eser, 2014), 33639 to 35886 kg/ha in Kahramanmaraş conditions (İdikut et al., 2016) and 35458 to 49406 kg/ha in Erzurum conditions (Stansluos et al., 2020a). It was determined that the correlation between green mass yield and grain protein content was negative and significant (r=-0.63). The correlation coefficient between the SPAD value and green mass yield was not significant (r=0.15).

Ear Length, Ear Diameter and Number Kernels per Ear

The ear lengths of the genotypes ranged between 13.1-20.9 cm in 2022 and 13.1-22.8 cm in 2023. The shortest ears were measured in Taşören landrace in both years, the longest ears Khan F_1 and Challenger F_1 in the first year and Argos F_1 and Khan F_1 in the second year (Table 5). Ear length is an important yield component with a high degree of heritability and is positively correlated with grain yield (Lucchin et al., 2003; Ruiz de Galarreta & Alvarez, 2001). In this study, hybrid varieties formed longer ears than landraces. The ear lengths of sweet corn varieties were less than the values reported by Sönmez et al. (2013) as 21.9-23.8 cm and close to the values reported by Stansluos et al. (2020b) as 16.1-19.8 cm. It can be stated that the ear lengths of landraces are close to the results reported by Lucchin et al. (2003) and Öztürk and Büyükgöz (2021). The correlations between ear length and ear diameter (r=0.61), kernel number per ear (r=0.84) and fresh ear yield (r=0.78) were positive and significant (Table 6).

The ear diameters of the genotypes varied between 41.7-51.3 mm in 2022 and 40.3-51.2 mm in 2023. As average of the years, it was determined that the ear diameter was the largest in Baron F_1 and Simpatico-KWS varieties, and the smallest was in Sayraç and Taşören landraces (Table 5). Ear diameter is a trait that can vary according to genetic structure, environmental factors and cultivation techniques, and affects kernel yield through the number of kernel rows per ear and the number of kernels per ear. In terms of ear diameter, significant differences among genotypes have also been identified in sweet corn (Sönmez et al., 2013; Stansluos et al., 2020b) and in maize landraces (Öztürk & Büyükgöz, 2021; Ruiz de Galarreta and Alvarez, 2001). In this study, the landraces generally had smaller ear diameters than the hybrids varieties, and positive and significant correlations were determined between the ear diameter and kernel number per ear (r=0.69) and fresh ear yield (r=0.60) (Table 6).

As an average of the trial years, the number of kernels per ear of genotypes varied between 231.9 and 692.0. The kernel number per ear was highest in Argos F_1 and Baron F_1 cultivars, and the lowest in Sayraç and Taşören landraces (Table 5). The hybrids were significantly superior to landraces in terms of the number of kernel rows per ear and kernel number per ear. Kernel number per ear is one of the most important component of yield in corn (Bagrintseva, 2015) and in this study, it was positively and strongly correlated (r=0.91) with fresh ear yield. In previous studies, significant differences between genotypes in terms of this trait were determined, and Öztürk & Büyükgöz (2021) and Stansluos et al. (2020a) reported similar results to our findings in corn landraces and in sweet corn varieties, respectively.

Fresh Ear Yield and Grain Protein Content

While fresh ear yield was 22274 kg/ha in 2022, it decreased significantly in 2023 due to the decrease in plant density and became 20215 kg/ha (Table 5). On average, fresh ear yields of corn genotypes ranged from 15312 to 25465 kg/ha. Significant differences between genotypes were identified, with all hybrid varieties yielding higher fresh ear yield than landraces. The highest fresh ear yield was obtained from the Khan F_1 variety, but the differences between it and other hybrid varieties were not significant. The Ormanüstü landrace had the lowest fresh ear yield and the differences between it and other landraces were found to be insignificant. Fresh ear yield is related to plant density, number of ear per plant, kernel number per ear and kernel weight, and may vary according to genotype, environmental factors and cultivation technique. In this study, fresh ear yields obtained from sweet corn varieties were higher than fresh ear yields from other studies, 12410 to 16100 kg/ha in İzmir (Bozokalfa et al. 2004), 10590 to 16370 kg/ha in Şanlıurfa (Öktem & Öktem, 2006), 13840 to 18620 kg/ha in Karaman (Eser, 2014), 11620 to 12450 kg/ha in Brazil (Okumura et al., 2014), 16190 to 19330 kg/ha in Sakarya (Uçak et al., 2016), 16330 to 18500 kg/ha in Tekirdağ (Özerkişi, 2016), and 9440 to 18790 kg/ha in Erzurum (Stansluos et al., 2020a). This result is thought to be mainly due to the fact that the plant density in this study was higher than in the studies listed.

The average grain protein contents of maize genotypes ranged from 10.4% to 16.2%. The Challenger F_1 sweet corn variety and the Karaçam landrace had the highest grain protein content, followed by the Argos F_1 and Ormanüstü genotypes. The lowest grain protein contents were determined in Simpatico-KWS and Baron F_1 varieties (Table 5). Protein content, which is the most important measure of kernel quality in corn, may vary significantly according to genetic structure, environmental factors and cultivation techniques. Sönmez et al. (2013) pointed out that sweet corn kernel contains higher protein than other variety groups, and Ünlü et al. (2018) drew attention to the wide variation in terms of grain protein content and biochemical properties in corn landraces in Türkiye. In previous studies conducted with sweet corn varieties, grain protein contents were determined between 11.6-20.5% (Goldman & Tracy, 1994) and 9.7-13.3% (Alan et al., 2014), and our results are consistent within these findings. In the studies conducted on corn landraces, protein content in dry grain were determined between 8.88-16.00% (Öner, 2011) and 11.02-14.50% (Öztürk & Büyükgöz, 2021).

Conclusion and Recommendations

In this study, plant number per hectare of corn genotypes was 86969-89585, the number of kernels per ear was 231.9-692.0, green-mass yield was 75337-108544 kg/ha, fresh ear yield was 15312-25465 kg/ha, and the kernel protein content was 10.4-16.2%. The highest green-mass yield was obtained from Simpatico-KWS, number of kernels per ear was obtained from Argos F_1, fresh ear yield was obtained from Khan F_1, and kernel protein content was obtained from Challenger F_1 and Karaçam genotypes. The Simpatico-KWS variety for silage has attracted attention with its high and stable yield in two years. It can be said that the Khan F_1, Argos F_1 and Challenger F_1 varieties can be preferred for fresh consumption. Considering the maturity days, the Signet F_1 variety may be the first choice for the Erzurum region. Despite the global warming process, it has been confirmed once again that only silage or corn for fresh consumption can be produced in Erzurum Plain conditions due to the short vegetation period and low average temperatures. After fresh cob harvest, genotypes with superior feed value of the remaining plant parts may be more advantageous in local conditions.

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