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DETERMINING THE GRAIN YIELD AND NUTRITIONAL COMPOSITION OF MAIZE CULTIVARS IN DIFFERENT GROWING GROUPS

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ABSTRACT

Due to its adaptability to different climates, different growing times, high photosynthetic capacity, nutrient value, and yield, maize is an important crop that is widely grown all over the world. This study was conducted to determine the grain yield and some nutrition traits of 18 maize cultivars under the ecological conditions prevalent in Bilecik in the years 2019 and 2020. Experiments were carried out in randomized complete block design with three replications. There were significant ($P<0.01$) differences among the cultivars in terms of grain yield and all quality traits. In addition, there were significant differences between the two years in terms of the investigated traits except for potassium, neutral detergent fiber, and total phenolic and ash content. According to the two year-average; grain yield (TV), test weight (TW), thousand grain weight (TGW), ash (AC), fat (FC), protein (PC), starch (SC), acid detergent fiber (ADF), neutral detergent fiber (NDF), and total phenolic (TP) contents of the maize cultivars were 13.00 ton ha^{-1}, 73.85 kg, 317.76 g, 1.59%, 5.95%, 11.22%, 65.69%, 4.25%, 15.17%, and 7.16 mg GA/g, respectively. The condensed tannin (CT), free radical scavenging activity (DPPH), total flavonoid (TF), potassium (K), phosphorus (P), magnesium (Mg), zinc (Zn), iron (Fe), manganese (Mg), and copper (Cu) contents were 0.39%, 7.97%, 0.48 mg QE/g, 4.24 g kg^{-1}, 3.58 g kg^{-1}, 1.24 g kg^{-1}, 2.36 g 100g^{-1}, 0.96 g 100g^{-1}, 0.67 g 100g^{-1}, and 0.20 g 100g^{-1}, respectively. The highest of grain yield were determined of the maize cultivars of ADA-9510 Larigal, Kerbanis, Keravnos, SY-Inove, Dracma, Kilowatt, ADA-9516 and SY-Gladius. According to the Biplot graph, the cultivars ADA-9510, SY-Inova, SY-Gladius, Kalideas, Dracma, Kerbanis, and Keravnos were prominent in terms of TV, SC, DPPH, TP, NDF, CP. The cultivars Arifiye, SY-Antex, Kolessaus, and Sakarya were prominent in terms of many quality traits such as PC, FC, AC, TF, TW, ADF, K, P, Mg, Fe, Zn, and Mn.

Keywords: Bilecik, corn, protein, total phenolic, quality, yield

INTRODUCTION

Cereals are rich sources of carbohydrates, proteins, lipids, minerals, and vitamins. Therefore, they play an important role in solving malnutrition problems all over the world (Nawaz et al., 2013). Maize (*Zea mays* L.) is an important crop that is cultivated widely across the globe. With a greater yielding potential than the other cereals, it ranks first in grain production with an annual yield of 1.1 billion tons globally (FAO, 2020). Maize, which is a C4 plant with different growing times and high yield, is a species with a high photosynthetic capacity. Its adaptability to different climates has allowed its agriculture to spread over large areas (Ozdemir and Sade, 2019). In addition to being used as human food and animal feed, maize is a resource for many unique industrial and commercial products such as breakfast foods, popcorn, alcohol, starch, glucose, spirits, oil, semolina, paint, soap, glue, insecticides, shaving cream, toothpaste, rubber tires, rayon, and molded plastics, etc. (Balconi et al., 2007).

Of the world corn production is used 60% for animal feed, 20% for human food (direct consumption), 10% for food processing and 10% for other purposes and as seeds. Maize serves as a staple food for a large proportion of the world's population and in certain countries. The chemical content of the maize grain is very important for human and animal diets. Maize grains have high levels of starch, protein, different sugar derivatives, fiber, and fat content, as well as significant amounts of iron, magnesium, potassium, vitamin A, B1, B3, B9, and C (White and Johnson, 2003). Additionally, maize flour is considered to be superior to wheat, rice, and oats in terms of nutritional and antioxidant properties (Nawaz et al., 2013). While maize stands out as a significant source of human food in developing countries, it is used more as animal feed and industrial raw material in developed countries. Especially in emerging countries, maize accounts for up to 60% of the daily intake of protein. It also supplies different vitamins and minerals that are important for the human diet, particularly for children, the elderly, and pregnant women (Ozcan, 2009).

A significant number of metabolic disorders and diseases result from malnutrition. Considering that the vast majority of the global population consumes maize as the main bread grain, more detailed knowledge of the nutritional properties of maize cultivars will be beneficial in the production of maize with improved nutritional quality (Ndukwe et al., 2015).

Worldwide research shows that the global agricultural crop production must be doubled by 2050 to meet the growing demand driven by population growth, dietary changes, and biofuel consumption (Akgun et al., 2019). The two ways generally adopted to meet these increasing demands are expanding the cultivation areas and increasing the yield to be obtained per unit area. As with many cultivated plants in the world, it is not possible to expand maize cultivation areas any further. Because the final limit has already been reached in agricultural fields that can be cultivated. Thus, it is evident that corn production can be enhanced only by increasing the yield per unit area. To this end, in addition to determining the appropriate cultivation techniques, it is necessary to develop high-yielding and high-quality cultivars that can adapt to the conditions of the region they are grown (Uysal, 2019).

The purpose of this study was to investigate the grain yield and nutritional content per grain in 18 maize cultivars of different maturity groups.

MATERIALS AND METHODS

Plant Materials and Field Experiments

In this study, a total of eighteen different maize cultivars registered in various institutions and organizations in Turkey were used (Table 1). This study was carried out in the field of the Agricultural Research and Application Center of the Faculty of Agriculture and Natural Sciences, Bilecik Seyh Edebali University (30° 10´ N, 40° 11´ E and 500 m) in the years 2019 and 2020.

Table 1. FAO groups and institutions/organizations of the cultivars used in the trials

Cultivar name	FAO group	Registration date	Name of institution and organization
AGA	720	2015	Sakarya Maize Research Institute, Turkey
Samada-07	700	2009	Sakarya Maize Research Institute, Turkey
Keravnos	700	2020	KWS, Turkey
Kilowatt	700	2013	KWS, Turkey
Kolessous	680	2012	KWS, Turkey
Sakarya	650	2005	Sakarya Maize Research Institute, Turkey
Arifiye	650	1972	Sakarya Maize Research Institute, Turkey
Ada-523	650	2000	Sakarya Maize Research Institute, Turkey
Ada-9516	650	2000	Sakarya Maize Research Institute, Turkey
Ada-9510	650	2000	Sakarya Maize Research Institute, Turkey
Larigal	600	2006	Sakarya Maize Research Institute, Turkey
SY-Gladius	600	2019	Sygenta, Turkey
Kerbanis	550	2013	KWS, Turkey
SY-Inove	450	2015	Sygenta, Turkey
Dracma	450	1998	Sygenta, Turkey
SY-Antex	400	2018	Sygenta, Turkey
Kalideas	250	2016	KWS, Turkey
Simpatico	200	2021	KWS, Turkey

The climate data for 2019 and 2020 were obtained from the Turkish State Meteorological Service and are given in Table 2. While the average temperature for long years was 21.0 °C, it was determined to be 20.8 °C and 20.7 °C for 2019 and 2020, respectively. The total rainfall for 2019, 2020, and long years were determined to be 182.4 mm, 229.0 mm, and 206.9 mm, respectively. In addition, the average relative humidity in 2019, 2020, and long years was 64.0%, 63.8%, and 62.8%, respectively.

The soil at the trial site had similar physical and chemical properties in both 2019 and 2020. The physical soil characteristics showed that the soil texture was loamy sand with low organic matter and clay. The trials were performed in the soil with the following characteristics: 2.18 dSm^{-1} slightly salty, 7.72 pH, 1617 kg ha^{-1} exchangeable potassium (K_2O) content, 254 kg ha^{-1} available phosphorus content (P_2O_5), and 1.32% organic matter.

In the trials, sowing was done on May 3, 2019 in the first year, and on May 6, 2020 in the second year in randomized blocks design with three replications. Each plot consisted of 4 rows that were 5 m in length and 70 cm apart from each other. In the trials, the distance between the plots was 1 meter and the blocks were 2 meters apart from each other. The number of seeds was calculated as 80000 seeds per hectare. Based on the soil analysis results, all the plots in the trials were fertilized with 39.1 kg N and 100 kg P_2O_5 per ha^{-1} (di-ammonium phosphate) during sowing. When the plants are 40-50 cm (V4- V6 leaf stage), urea (% 46 N) fertilizer was divided into two parts and given to the soil during the first hoeing and throat filling. The total rate of N applied was 200 kg ha^{-1}. In the experiment, drip irrigation system was used, and irrigation was applied at weekly intervals or as needed. All cultivars were given the same amount of water at the same time. Pest and weed controls were performed according to general local practices and recommendations. Ten plants were randomly selected per plot to determine the yield and quality traits. Harvesting was done by hand (on Oct 5 2019 in the first year and on Oct 7 2020 in the second year) after the sheath of the cob had dried completely.

Table 2. Meteorological data for the experiment areas

Months	Temperature (°C)			Rainfall (mm)			Relative humidity (%)		
	LY	2019	2020	LY	2019	2020	LY	2019	2020
May	16.1	16.7	17.5	47.7	55.2	35.0	64.5	62.0	60.1
June	19.9	19.8	19.0	39.3	139.1	62.4	62.0	59.7	68.0
July	21.7	22.9	23.8	30.9	1.2	35.4	61.0	63.0	60.3
August	23.5	22.4	23.3	11.2	9.9	6.5	62.0	60.9	56.7
September	19.3	19.1	21.4	31.2	4.7	8.0	64.3	67.0	65.2
October	14.2	16.0	17.1	46.6	18.9	35.1	70.4	69.9	66.6
Average	**19.1**	**19.5**	**20.4**				**64.0**	**63.8**	**62.8**
Total				**206.9**	**229.0**	**182.4**			

Grain yield, physical and chemical analyses

The cobs of the ten randomly selected plants were blended. The grain moisture was determined by drying the collected grains in an oven. The grains from each plot were weighed and the value obtained was corrected for 14% humidity. Subsequently, the resulting values were converted into grain yield as tons per hectare. Test Weight (TW) was determined using the special apparatus according to the 55-10 Approved Methods (AACC, 2010) and expressed in kilograms per hectoliter (kg/hL). Thousand grain weight (TGW) was determined by weighing 1000 seeds counted with a seed counting device (Chopin technologies-Numigral).

Maize grains that were separated for chemical analyses were ground in a hammer mill to pass through a 0.5 mm sieve. The ground samples were stored at ±4 C in a cold storage unit until they were analyzed. In the ash analyse, the temperature of the furnace was gradually increased to 500 ºC and the samples were burned for 8 hours at this temperature until completely ashed. Fat content was determined with the Soxhlet method (Welch, 1977). Protein content was determined with the use of the Micro Kjeldhal method of Concon and Soltess (1973). Starch contents of the samples were determined with the aid of enzymatic test kits (Megazyme) according to the AACC Approved Methods 76-13.01 (AACC, 2000). ADF and NDF values were determined in an ANKOM 220 Fiber Analyzer device (Van Soest et al., 1991) in maize grains. The total flavonoid content was determined according to Arvouet-Grand et al. (1994) with some modifications. Each sample (200 µL) was mixed with 100 µL of aluminum nitrate (10%) and 100 µL of potassium acetate (1 M). The total volume of the solution was adjusted to 5mL with ethanol. Similarly, a blank was prepared by adding methanol in place of the sample. Absorbance measurements were read at a spectrophotometer at the absorbance value of 417 nm after 40 min incubation at room temperature in dark conditions. Total flavonoid content was expressed as mg equivalents of quercetin (QE) g-1 DW according to the equation obtained from the standard quercetin graph and calculated from the calibration curve (R2= 0.9994) (Yavuz and Gulumser, 2022). The effect of each sample on the 2,2-diphenyl-1-picryl-hydrazylhydrate (DPPH) radical was identified according to Gezer et al. (2006). The total condensed tannin content was determined by adding 6 ml of tannin solution to 0.01 g of ground seed, then placing it in a tube and mixing on a vortex. The tubes were tightly capped and kept at 100 ° C for 1 hour and the samples were allowed to cool (Yildirim et al., 2021; Yildiz et al., 2021). Then, they were read at a spectrophotometer at the absorbance value of 550 nm (Bate Smith, 1975). Condensed tannins were calculated by the following formula: absorbance (550 nm x 156.5 x dilution factor) / Dry weight (%). Mineral matter analysis was performed with the ash samples obtained to determine the ash content. Subsequently, 1 N HCl was added to the ash samples and left to sit for 30 minutes. Subsequently, the samples were filtered with filter paper and diluted up to 50 mL with ultrapure water. The potassium, magnesium, zinc, iron, manganese, and copper contents were determined through inductively coupled plasma mass spectrometry (ICP-MS) using a Thermo Scientific - iCAPQc (Bremen, Germany). The phosphorus content was determined by the "Olsen" method (Olsen and Sommers, 1982).

Statistical Analysis

The combined data of the two years was subjected to an analysis of variance utilizing a randomized complete block design. Statistical analysis was performed using the Minitab 19 package program. Means were compared with LSD test ($p<0.05$). The principal component analysis (PCA) was performed based on all the investigated traits and the relationship between the genotypes. A Biplot graph was created by using the JMP 13 statistical package program (JMP, 2013).

RESULTS AND DISCUSSION

Table 3 shows the mean, SEM, SD, minimum, and maximum values of the investigated traits of the maize cultivars included in our study. Tables 4, 5, and 6 indicate that the effect of the year was highly significant on investigated traits, except for DM, AC, NDF, TF, and K. For all of the traits investigated (except for DM), there were very significant (P>0.01) differences among genotypes (Table 4, 5, and 6). These results indicate that the year and cultivars significantly impacted on investigated traits that were expressed by the maize cultivars.

Table 3. The mean values and ranges of the grain yield and 19 quality traits of the 18 maize cultivars in the combined data of the years.

Traits	Mean	SEM	SD	CV	Range	
					Minimum	Maximum
Grain yield (ton ha^{-1})	13.00	0.45	1.91	8.71	9.58	16.44
Test weight (kg)	73.85	0.43	1.80	2.44	70.06	76.86
Thousand grain weight (g)	317.76	9.77	5.46	7.05	200.29	380.10
Ash (%)	1.59	0.02	0.07	4.26	1.49	1.74
Fat (%)	5.95	0.17	0.73	4.19	5.01	7.44
Protein (%)	11.22	0.19	0.82	7.26	10.12	13.24
Starch (%)	65.69	0.42	1.80	2.73	62.39	68.45
Acid detergent fiber (%)	4.25	0.11	0.46	6.86	3.65	5.22
Neutral detergent fiber (%)	15.17	0.15	0.65	4.30	13.96	16.41
Total phenolic (mg GA/g)	7.16	0.22	0.94	6.08	5.88	9.53
Condensed tannin (%)	0.39	0.00	0.01	3.66	0.36	0.42
Free radical scavenging activity (%)	7.97	0.22	0.91	5.42	6.21	9.93
Total flavonoid (mg QE/g)	0.48	0.02	0.08	5.92	0.31	0.61
Potassium (g kg^{-1})	4.24	0.06	0.24	5.61	3.77	4.72
Phosphorus (g kg^{-1})	3.58	0.06	0.26	7.38	3.18	4.24
Magnesium (g kg^{-1})	1.24	0.04	0.15	3.03	1.00	1.55
Zinc (g 100g^{-1})	2.36	0.07	0.28	3.06	1.92	2.79
Iron (g 100g^{-1})	0.96	0.04	0.15	4.52	0.72	1.27
Manganese (g 100g^{-1})	0.67	0.02	0.07	5.16	0.51	0.79
Copper (g 100g^{-1})	0.20	0.01	0.03	3.92	0.16	0.30

SEM: Standard error of mean; SD: Standard deviation; CV: Coefficient of Variation

The grain yield of the maize cultivars ranged from 9.58 t ha^{-1} (SY-Antex) to 16.44 t ha^{-1} (ADA-9510). In terms of grain yield, the cultivars Keravnos, Kilowatt, SY-Gladius, Kerbanis, SY-Inove, Dracma, ADA-9510, Larigal, and ADA-9516 were placed in the same statistical group. The mean test weight ranged from 70.06 kg (Dracma) to 76.86 kg (Simpatico) with a mean value of 73.85 kg. It is thought that the difference between cultivars in terms of yield may be due to the difference in the FAO group, genetic structure and environmental factors. Thousand grain weights ranged from 200.29 g (Samada-07) to 380.10 g (SY-Gladius) with a mean value of 317.76 g (Tables 3 and 4). Although there is not much difference in rainfall between years, it is thought that very little rainfall in July in 2019 may have resulted in low yields. The rainfall during the 2019 growing season (229.0 mm) was more favorable for the expression of GY, TW, and TGW among the cultivars than the rainfall in 2020 (182.4 mm) (Table 2). Videnovic et al. (2013) stated that the grain yield in maize varies from year to year. Climatic factors such as temperature, sunshine hours, and precipitation besides genetic factors were the primary factors affecting maize growth and yield (Zhou et al., 2016). Ilker et al. (2009) reported that genotypes were affected by the environment and that some genotypes had higher yields due to high levels of environmental adaptation. Sahin and Kara (2021) reported that cultivars with a high grain yield had high thousand grain and test weights while cultivars with low grain yield had the lowest values of thousand grain and test weights due to having a higher number of grains per ear. It was reported by the researchers that the differences in grain yield, test weight, and thousand grain weight may be caused by ecological factors and agricultural practices, particularly by cultivar traits (Bayisa et al., 2022). Erawati et al. (2021) reported that each cultivar has a specific level of resistance and different genetic potential in responding to its environment. They also suggested that cultivars have the potential to provide high yields, but when environmental conditions are not favorable, then the variety cannot realize its full potential. Kalkan and Sade (2009) reported that grain yield may vary according to the maturity groups in a study they conducted on hybrid maize cultivars with different FAO groups in Konya. In the study, cultivars in the FAO 400, 250 and 200 groups showed low yields when compared to other cultivars.

Macronutrients such as fat, protein, and carbohydrates provide energy and materials that are important to ensure body composition while micronutrients such as vitamins and minerals ensure the metabolic pathways and the role of macronutrients (Biesalski and Tinz, 2018). The average ash, fat, protein and starch contents of the maize grains were 1.59% (range: 1.49-1.74%), 5.95% (range: 5.01-7.44%), 11.22% (range: 10.12-13.24%), and 65.69% (range: 62.39-68.45%), respectively (Table 3). The ash and protein was higher in the first year (1.60% and 11.36%) than in the second year (1.58% and 11.09%). The fat and starch contents of the cultivars were higher in the second year (6.28% and 66.93%) than in the first year (5.63% and 64.45%) (Table 4). Ash content is defined as the total amount of minerals accumulated in the seeds. Ali et al. (2010) indicated that the ash content of maize grains was 1.07 - 1.16%. Lipids are a diverse group of compounds with different functions such as energy storage and a structural component of cell membranes (Fahy et al., 2011). It is known that maize has a high concentration of lipids among cereals, following oat. In previous studies on maize, a wide range of fat content has been reported, namely 3.21 – 7.71% (Ullah et al., 2010). The protein content of maize grains is an important quality parameter. It was reported in previous studies that the protein contents were influenced by genotypes, location, and cultural practices (Seebauer et al., 2010). The protein content of maize cultivars was reported to be between 8.50% and 10.49% by Irinkoyenikan et al. (2016). Starch is the primary digestible carbohydrate of the plants, thus offering an important source of energy in human nutrition and animal feeding. Beckles and Thitisaksakul (2014) reported that cultivars, rainfall, temperature, soil type, and growth conditions could be more effective on the starch content in grains than genetic conditions. Previous studies have reported that the starch content of maize cultivars ranges from 38.83% to 67.09% (Thakur et al., 2021). Hegyi et al. (2007) reported that different maturity groups had significant effects on yield and some quality traits.

Table 4. Two-year average values for grain yield and some quality traits of the 18 maize cultivars

	GY		TW		TGW		AC		FC		PC		SC	
Cultivar	**		**		**		**		**		**		**	
AGA	13.00	b-f	73.10	abc	359.34	abc	1.54	cde	6.67	ab	10.12	f	66.11	a-e
Samada-07	12.94	b-g	74.21	ab	200.29	i	1.54	cde	6.26	bcd	11.97	bcd	65.91	a-e
Keravnos	14.93	abc	73.12	abc	313.65	efg	1.55	c-e	6.12	b-e	10.60	ef	66.89	a-d
Kilowatt	14.25	a-d	73.55	abc	369.50	ab	1.69	ab	5.34	efg	11.45	cde	64.11	b-e
Kolessous	11.81	c-g	76.42	a	310.80	efg	1.57	b-e	5.76	d-g	11.42	cde	66.49	a-d
Sakarya	11.06	d-g	74.83	ab	340.00	b-e	1.51	de	6.00	b-e	10.77	ef	65.36	a-e
Arifiye	10.49	efg	75.51	ab	300.99	fg	1.58	b-e	7.22	a	13.24	a	62.39	e
Ada-523	11.97	b-g	74.71	ab	329.10	c-f	1.55	cde	6.28	bcd	11.08	def	65.57	a-e
Ada-9516	13.77	a-e	74.40	ab	274.17	h	1.49	e	6.64	abc	11.49	cde	65.21	a-e
Ada-9510	16.44	a	72.49	bc	287.79	a-d	1.57	b-e	5.15	g	10.60	ef	67.40	ab
Larigal	15.31	ab	71.93	bc	324.51	def	1.70	ab	6.32	bcd	11.05	def	64.27	b-e
SY-Gladius	13.32	a-f	74.24	ab	380.10	a	1.58	b-e	5.50	d-g	10.59	ef	67.00	abc
Kerbanis	13.46	a-e	73.26	abc	339.80	b-e	1.62	a-d	5.22	fg	11.16	c-f	65.27	a-e
SY-Inove	14.90	abc	71.82	bc	350.70	gh	1.57	b-e	5.01	g	10.51	ef	68.45	a
Dracma	14.28	a-d	70.06	c	311.54	efg	1.58	b-e	5.25	fg	10.70	ef	67.48	ab
SY-Antex	9.58	g	76.42	a	336.10	cde	1.65	abc	7.44	a	12.13	abc	63.08	cde
Kalideas	12.52	b-g	72.32	bc	281.75	gh	1.62	a-e	5.19	fg	10.59	ef	68.36	a
Simpatico	10.00	fg	76.86	a	309.56	efg	1.74	a	5.83	c-g	12.56	ab	63.02	de
Year	*		**		**		ns		**		*		**	
2019	12.66	b	71.47	b	310.35	b	1.60		5.63	b	11.36	a	64.45	b
2020	13.34	a	76.22	a	325.18	a	1.58		6.28	a	11.09	b	66.93	a

*: Significant at the p<0.05 probability level, **: Significant at the p<0.01 probability level, ns: non-significant, GY: Grain yield (ton ha-1), TW: Test weight (kg), TGW: Thousand grain weight (g), AC: Ash content (%), FC: Fat content (%), PC: Protein content (%), SC: Starch content (%)

The average ADF and NDF contents of maize cultivar ranged from 3.65% (Arifiye) to 5.22% (Larigal) and from 13.96% (Arifiye) to 16.41% (Kilowatt), respectively. ADF and NDF values were higher in the second year. However, statistical differences were observed in ADF between the years, but not in NDF. ADF indicates the amount of cellulose, lignin, and insoluble protein in the plant cell wall structure. It is also a good indicator of feed digestibility and energy intake of the animal. It has been reported that the digestibility and energy value of feeds containing high ADF are low (Mut et al., 2017). NDF expresses the amount of cellulose, hemicellulose, lignin, cutin, and insoluble protein in the plant cell wall structure. Since the NDF value directly affects the feed intake of the animals, the lower this value is the higher the animal's feed intake in the terms of feed (Van Soest et al., 1991). These values are very important in maximizing feed quality. Radosavljevic et al. (2012) reported that the ADF and NDF values ranged from 3.89% to 4.88% and from 17.59% to 29.84%, respectively.

Measuring the levels of various antioxidants in different maize cultivars provides key information for efforts to improve the antioxidant levels in corn. In this study, the average TP, CT, DPPH, and TF contents of the maize grain were 7.16 mg GA/g (range: 5.88 mg GA/g– 9.53 mg GA/g), 0.39% (range: 0.36% - 0.42%), 7.97% (range: 6.21% - 9.93%), and 0.48 mg QE/g (range: 0.31 mg QE/g - 0.61 mg QE/g), respectively (Tables 3 and 5). Natural antioxidants, especially phenolics and flavonoids, are safe and bioactive. Flavonoids show antioxidant activity and have considerable effects on human nutrition and health. In recent decades, phenolic and flavonoid-rich natural diets with antioxidant activity have fostered an interest in nutrition and food science (Aryal et al., 2019). DPPH is one of the most important methods adopted for evaluating the antioxidant properties of plants. Condensed tannins contribute to astringency in foods (Dykes and Rooney, 2007). These compounds are abundantly present in maize, especially in bran (Shah et al., 2016). Biofortification to produce corn with improved antioxidant activities could be a solution for some health problems. The researches have suggested that the phytochemicals in grains demonstrate significant beneficial contribution in reducing the risk of many diseases due to their potent antioxidant activities (Shahidi, 2009). Maize grains contain nutritionally valuable antioxidants that benefit human health by reducing age-related disorders such as cardiovascular disease, diabetes, obesity, neurodegenerative disorders, and cancer (Bae et al., 2021). Therefore, maize is considered to be a functional food. In addition, previous studies showed that the flavonoids and phenolic compounds have positive effect on the productivity and health of animals, as well as rumen fermentation and the control of nutritional stress such as bloat and acidosis (Lee et al., 2017). These compounds also have indirect effects on the environment. Lascano and Cardenas (2010) reported that ¼ of the methane gas released into the atmosphere is produced in the digestive system of ruminants. Condensed tannins inhibit certain hydrogen-producing protozoans and methane-producing organisms that use hydrogen directly in the rumen, and reduce greenhouse gas emissions (Martin et al., 2016). But tannin binds to proteins, carbohydrates, and minerals, which decrease the digestibility of these nutrients and reduce the feed efficiency of ruminants and monogastrics during feeding. Martinez-Martinez et al. (2019) reported that the total phenolic, flavonoid, and DPPH contents of the maize grain ranged between 69.46 mg GAE $100g^{-1}$ and 137.39 mg GAE $100g^{-1}$, 0.02 mg QE g^{-1} and 0.19 mg QE g^{-1} and 3.17% and 6.75%, respectively. Nawaz et al. (2013) reported that the condensed tannins content of the maize grain ranged between 0.494 g/100 g and 0.556 g/100 g.

Table 5. Two-years average values for some quality traits of 18 maize cultivars

Cultivar	ADF	NDF	TP	CT	DPPH	TF
	**	**	**	**	**	**
AGA	4.95 ab	14.54 def	7.45 b	0.39 abc	7.90 b-e	0.49 cde
Samada-07	4.14 b-f	14.83 c-f	7.08 bcd	0.36 c	8.81 abc	0.45 def
Keravnos	4.25 b-f	14.79 c-f	7.32 bc	0.38 bc	8.54 abc	0.41 efg
Kilowatt	4.81 abc	16.41 a	7.51 b	0.40 abc	7.73 b-e	0.60 ab
Kolessous	4.44 a-f	14.95 b-f	6.73 bcd	0.39 abc	7.27 b-e	0.56 abc
Sakarya	4.06 c-f	14.73 c-f	5.90 c	0.39 abc	6.26 de	0.61 a
Arifiye	3.65 f	13.96 f	7.11 bcd	0.39 abc	8.03 bc	0.56 abc
Ada-523	4.75 a-d	15.54 a-d	7.41 b	0.37 bc	7.81 b-e	0.39 fg
Ada-9516	3.69 f	14.32 ef	6.50 bcd	0.39 abc	8.60 abc	0.52 a-d
Ada-9510	4.03 c-f	15.33 a-e	7.06 bcd	0.40 abc	8.56 abc	0.31 g
Larigal	5.22 a	16.11 ab	9.53 a	0.39 abc	9.93 a	0.45 def
SY-Gladius	4.03 c-f	15.29 a-e	7.11 bcd	0.39 abc	8.17 bc	0.50 b-e
Kerbanis	4.25 b-f	15.85 abc	9.13 a	0.42 a	8.95 ab	0.49 cde
SY-Inove	3.85 ef	15.36 a-e	6.65 bcd	0.38 abc	8.01 bcd	0.39 fg
Dracma	3.73 f	15.44 a-e	7.52 b	0.40 ab	7.10 cde	0.51 b-e
SY-Antex	4.69 a-e	14.45 def	5.88 d	0.37 bc	6.21 e	0.46 def
Kalideas	3.96 def	15.38 a-e	6.46 bcd	0.40 ab	7.60 b-e	0.48 c-f
Simpatico	4.05 c-f	15.81 abc	6.56 bcd	0.40 abc	8.03 bc	0.48 c-f
Year	**	ns	ns	**	**	**
2019	3.76 b	15.08	7.18	0.40 a	7.16 b	0.31 b
2020	4.75 a	15.26	7.14	0.38 b	8.78 a	0.65 a

**: Significant at the p<0.01 probability level, ns: non-significant, ADF: Acid detergent fiber (%), NDF: Neutral detergent fiber (%), TP: Total phenolic (mg GA/g), CT: Condensed tannin (%), DPPH: Free radical scavenging activity (%), TF: Total flavonoid (mg QE/g)

The mineral composition of the maize grain is an important parameter that needs to be considered in human nutrition and feed animal. The results of the mineral content grains of different maize cultivars are shown in Table 6. The analysis shows the level of K (3.77 g kg^{-1}- 4.72 g kg^{-1}), P (3.18 g kg^{-1}- 4.25 g kg^{-1}), Mg (1.00 g kg^{-1} - 1.55 g kg^{-1}), Zn (2.79 g $100g^{-1}$ - 1.92 g $100g^{-1}$), Fe (0.72 g $100g^{-1}$ - 1.27 g $100g^{-1}$), Mn (0.51 g $100g^{-1}$ - 0.78 g $100g^{-1}$), and Cu (0.16 g $100g^{-1}$ - 0.30 g $100g^{-1}$) (Tables 3 and 6). The K, Mg, Zn, Fe, and Cu contents of the genotypes were higher in the first year while the P, Mg, and Mn contents were higher in the second (Table 6). In previous studies, it was reported that magnesium content varies depending on the cultivar (Ullah et al., 2010), years (Ferreira et al., 2012), environments (Gu et al., 2015), and agricultural practices (Kresovic et al., 2018). Mineral deficiencies influence billions of people around the world. Mineral insufficiency causes decreased working efficiency, cardiovascular diseases, cancer, autoimmune diseases, high healthcare costs, and increased rates of premature death. Therefore, mineral elements such as Cu, Ca, Mn, Zn, and Fe are important from the viewpoint of malnutrition (Welch and Graham, 2004). The maize grain is an excellent and relatively inexpensive source of certain minerals, especially in underdeveloped countries. In recent years, one of the aims of plant breeding programs has been to increase mineral accumulation in cereal grains. This approach is a sustainable strategy to increase the use of micronutrients in diets as there are no further costs once new cultivars are developed (Neeraja et al., 2017). In a previous study on the mineral content of maize grains in different cultivars, Ullah et al. (2010) determined that the maize grain contained K (2915 ppm - 3471 ppm), Na (540.30 ppm - 620.41 ppm), Ca (410 ppm -5 90 ppm), Fe (38.02 ppm - 56.14 ppm), Zn (37.05 ppm - 52.04 ppm), Mg (985.2 ppm - 1125.3 ppm), and Cu (11.02 ppm - 14.25 ppm).

Table 6. Two-year average values for mineral matter contents of the 18 maize cultivars

	K	P	Mg	Zn	Fe	Mn	Cu
Cultivar	**	**	**	**	**	**	**
AGA	3.97 cd	3.68 bcd	1.28 a-e	2.05 ef	0.90 c-f	0.73 abc	0.23 bc
Samada-07	4.15 bcd	3.47 c-f	1.23 a-e	2.03 ef	0.83 ef	0.70 a-f	0.30 a
Keravnos	4.02 cd	3.45 c-f	1.13 b-e	1.92 f	0.92 cde	0.65 c-g	0.19 bc
Kilowatt	4.72 a	3.63 b-e	1.32 a-e	2.27 b-f	1.02 bcd	0.76 ab	0.17 c
Kolessous	4.14 cd	3.56 b-e	1.27 a-e	2.58 abc	0.94 b-e	0.78 a	0.19 bc
Sakarya	4.12 cd	3.76 bc	1.27 a-e	2.73 a	1.13 ab	0.70 a-f	0.21 bc
Arifiye	4.42 abc	4.25 a	1.55 a	2.64 ab	1.25 a	0.71 a-e	0.19 bc
Ada-523	3.96 cd	3.74 bc	1.32 a-e	2.04 ef	0.88 c-f	0.72 a-d	0.24 ab
Ada-9516	3.77 d	3.90 ab	1.38 abc	2.19 def	0.78 ef	0.60 e-h	0.18 bc
Ada-9510	4.35 abc	3.28 ef	1.05 cde	2.00 ef	0.72 f	0.51 h	0.18 bc
Larigal	4.32 abc	3.60 b-e	1.32 a-e	2.79 a	1.27 a	0.66 b-g	0.18 bc
SY-Gladius	4.17 bcd	3.49 c-f	1.11 b-e	2.23 c-f	0.93 cde	0.58 gh	0.20 bc
Kerbanis	4.35 abc	3.50 c-f	1.20 b-e	2.34 b-e	0.85 def	0.61 e-h	0.17 c
SY-Inove	4.24 a-d	3.19 f	1.00 e	2.43 a-d	0.92 cde	0.60 fgh	0.18 bc
Dracma	4.35 abc	3.33 def	1.09 b-e	2.35 b-e	0.89 c-f	0.62 d-h	0.18 bc
SY-Antex	4.30 a-d	3.82 bc	1.42 ab	2.47 a-d	1.03 bcd	0.65 c-g	0.16 c
Kalideas	4.28 a-d	3.18 f	1.01 de	2.61 abc	0.86 def	0.65 c-g	0.20 bc
Simpatico	4.68 ab	3.68 b-e	1.34 a-d	2.76 a	1.06 bc	0.79 a	0.19 bc
Year	ns	**	**	**	**	**	*
2019	4.23	3.47 b	1.12 b	2.41 a	0.99 a	0.65 b	0.21 a
2020	4.25	3.70 a	1.35 a	2.30 b	0.93 b	0.68 a	0.19 b

*: Significant at the p<0.05 probability level, **: Significant at the p<0.01 probability level, ns: non-significant, K: Potassium (g kg^{-1}), P: Phosphorus (g kg^{-1}), Mg: Magnesium (g kg^{-1}), Zn: Zinc (g $100g^{-1}$), Fe: Iron (g $100g^{-1}$), Mn: Manganese (g $100g^{-1}$), Cu: Copper (g $100g^{-1}$)

Biplot Analysis

A genotype × trait Biplot was used to simultaneously demonstrate the relationships between traits and genotypes. The Biplot also helped identify the cultivars with superior traits. The two-year average values of the investigated traits of the 18 maize cultivars are displayed in Tables 4, 5, and 6. The Biplot graph explained 54.7% of the total variation (PCA1 33.9% and PCA2 20.8%) (Figure 1).

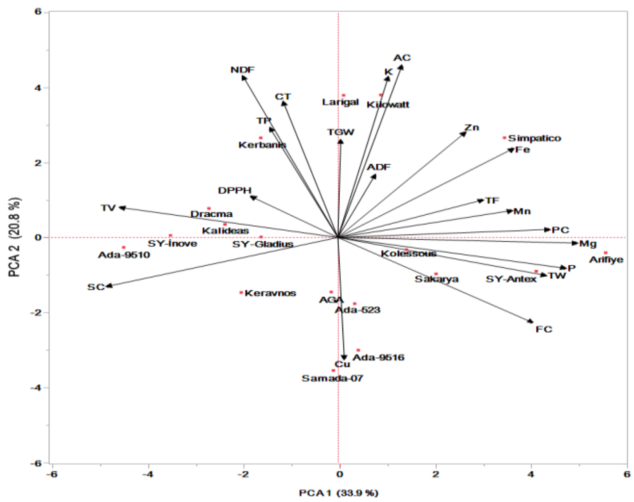

Figure 1. Genotype × Trait biplot graph for the investigated traits of the maize cultivars

In the Biplot graph, vector angles below 90° indicate that the traits are positively correlated; vector angles above 90° indicate a negative correlation, and finally, vector angles equal to 90° indicate that the traits are not related (Yan and Tinker, 2006). The vectors in Figure 1 were drawn individually from the biplot origin to each of the traits. The TV showed a highly significant and positive correlation with SC, DPPH, TP, NDF, CT, and TGW (<90˚). The cultivars ADA-9510, SY-Inova, SY-Gladius, Kalideas, Dracma, Kerbanis, and Keravnos were prominent in terms of grain yield. The cultivars Simpatico, Arifiye, SY-Antex, Kolessaus, and Sakarya were prominent in terms of many quality traits such as PC, FC, AC, TF, TW, ADF, K, P, Mg, Fe, Zn, and Mn. This result is partly consistent with a previous report (Amegbor et al., 2022). Yousaf et al. (2021) showed the negative association between starch and fat content.

CONCLUSIONS

Increasing the nutrient contents in cereals, which are the main food crops worldwide, is a sustainable approach to improving nutritional well-being. There are many types of maize in the market both in the world and in Turkey. However, although the yield and quality characteristics of these cultivars are different from each other, their responses to the ecology of the region may vary. Bilecik province is located in a region that is very suitable for grain mazie cultivation with its ecological conditions and irrigation facilities. As a matter of fact, the agricultural and quality traits determined in the cultivars used in the study were superior to the studies conducted in most regions of Turkey. The results of this study indicate that the grain yield and quality traits of many maize cultivars have significant differences. The highest of grain yield were determined of the maize cultivars of ADA-9510 Larigal, Kerbanis, Keravnos, SY-Inove, Dracma, Kilowatt, ADA-9516 and SY-Gladius. According to the Biplot graph, the cultivars ADA-9510, SY-Inova, SY-Gladius, Kalideas, Dracma, Kerbanis, and Keravnos were prominent in terms of grain yield. The cultivars Simpatico, Arifiye, SY-Antex, Kolessaus, and Sakarya were prominent in terms of many quality traits such as PC, FC, AC, TF, TW, ADF, K, P, Mg, Fe, Zn, and Mn. Knowing the change rates of nutritient values in maize cultivars will contribute to the farmer, user and industry field.

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