Original paper Open Access

Investigation of Agronomic and Kernel Quality Traits of Registered Maize Varieties using Principal Component Biplot Analysis

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Keywords: *Maize, Biplot analysis, yield, quality, agronomic traits*

Abstract

The aim of this study was to determine the adaptability and kernel quality of new maize hybrids in Bayramic-Canakkale ecological conditions (West part of Turkey). The field trials were carried out during the 2016 and 2017 planting seasons (spring) with 10 maize hybrids (A49, A9C1, A9C2, B4A, B4C, B4C2, B6C, BA, BC and BC2). Grain yields, some yield components and some grain quality characteristics (yield, protein content, total oil content and content of oleic acid, linoleic acid and linolenic acid) of hybrids maize were examined in this study. All kernel quality traits were mostly determined by the effect of the genotype. There were statistically significant differences among genotypes for all investigated agronomical and compositional quality traits. According to the results, significant differences were found between the genotypes and the years but the interaction of the two factors also had effect on all parameters. The hybrid named BC was outstanding compared to other hybrids for traits such as the thousand kernel weight, ear width, number of kernels per ear, first ear height and ear length. The BA hybrid had the highest values for plant height, day of silking and day of tasseling. In addition, there were positive and significant correlations between traits like ear width, number of kernels per ear and thousand kernel weight.

Introduction

Maize is the most important food source for people in America (especially middle and south), Africa and China (Anonymous, 2013) and grown on large areas for both animal and human nutrition. Maize is in the first rank in the world grain production. A maize plant was also grown in many countries for silage production in the last thirty years.

It is also used as a raw material for the production of alcohol, oil and other industrial purposes and its usage is gradually increasing compared to other cereals. The reason of this is that maize can give twice as more yield than barley and wheat from a unit area while its cultivation technique, harvesting, transportation and storage are easier (Ozata et al. 2013; Kusaksiz and Kusaksiz, 2018) compared to other cereals.

Because of the diversity found in the vegetative characteristics and yield of the maize varieties (Allard, 1999.; Argillier et al, 2000), maize breeders are aimed to develop superior maize genotypes in terms of more than one property and they use all of these traits for selection.

More than one year of trials are required to determine the performance of a genotype and compare it with other genotypes in the different environments, because vegetative characteristics and therefore yields of maize varieties can vary in different conditions (Argillier et al, 2000) Maize breeders are interested in detecting superior maize genotypes in terms of more than one feature when they carry out their selection.

There are significant differences among maize varieties in terms of quality characteristics such as yield, protein and oil content (Loucka et al, 2018). Although the genotype is the most determinant factor, the environmental conditions (year, precipitation, temperature etc.) could also have a significant effect on the grain yield and quality of maize (Kahriman et al, 2016). Thus, the environmental stability in maize properties is an important factor.

Stability of maize genotypes has already been analyzed in previous studies (Oz, 2012.; Badu-Apraku et al, 2013; Jayakumar et al, 2007). Biplot analysis method was used in many studies (Gabriel, 1971, Kahriman et al, 2016; Badu Apraku et al, 2013), where more than one

feature of the genotypes can be displayed graphically and visual comparison of the genotype and the relationships between the features are possible. Recently, many scientists use the GGE (Genotype × Genotype-Environment) Biplot analysis method and utilize it for plant breeding (Yan et al, 2000 and 2020; Yan, 2001; Kaya et al, 2006; Ilker et al, 2009; Fırıncıoglu et al, 2012; Kılıç et al, 2012).

Thus, the objective of this study was to evaluate the grain yield, yield components and compositional quality parameters of new maize (*Zea mays* L.) hybrids under Canakkale ecological conditions.

Materials and Methods

Experimental trials

The field trials were conducted during the 2016 and 2017 crop seasons, in the Çanakkale area, which is located in the Northwest part of Turkey with latitude of 39 degree and longitude of 26 degree (10 m above sea level). The area (Canakkale) is characterized by windy conditions for most of the year, with rate of humidity 72.6% registered in the experimental fields area. The 10 new hybrids included in the research and their parents are shown in Table 1. The field experiment was designed according to randomized block with three replications. Each plot consisted of four 8 m long rows 0.70 m apart, with a planting distance on the row of 0.20 m. The total area of each plot was 22.4 m2 and the harvest area of each plot was 9.8 m2. Sowing dates were 5 May 2016 and 5 May 2017.

Fertilization was applied such that 20 kg of N and 6 kg of P_2O_5 was present per 0.1 ha. Plots were watered according to plant needs. Cultural practices were applied as needed. The harvest as done when grain reached 15 % moisture. The temperature and precipitation values were lower for 2016 than for 2017 (see Table 2).

Table 1 - List of maize genotypes included in the research

Hybrid Number	Hybrid Code and crosses	Supplier Institution (region)
1	A49(14A4x18A9)	Sakarya Maize Reserch Research Institute (Turkey)
2	A9C1(18A9xC1)	Sakarya Maize research Institute, Cukurova Agriculture Research Institute(Turkey)
3	A9C2(18A9xC2)	Sakarya Maize research Institute, Cukurova Agriculture Research Institute(Turkey)
4	B4A(BATEM4x14A4)	West Mediterranean Research Institute, Sakarya Maize research Institute (Turkey)
5	B4C(BATEM4xC1)	West Mediterranean Research Institute, Cukurova Agriculture Research Institute (Turkey)
6	B4C2(BATEM4xC2)	West Mediterranean Research Institute, Cukurova Agriculture Research Institute (Turkey)
7	B6C(BATEM6xC1)	West Mediterranean Research Institute, Cukurova Agriculture Research Institute (Turkey)
8	BA(B1x14A4)	West Mediterranean Research Institute, Sakarya Maize research Institute(Turkey)
9	BC(B1xC1)	West Mediterranean Research Institute, Cukurova Agriculture Research Institute (Turkey)
10	BC2(B1xC2)	West Mediterranean Research Institute, Cukurova Agriculture Research Institute(Turkey)

Agronomical and quality traits

Table 2 - Weather parameters recorded* during the experimental trials (years 2016-2017) at Canakkale - Turkey (North -West Turkey)

Month	Average Temperature (°C)		Relative Humidity (%)		Total Precipitation (mm)	
Year	2016	2017	2016	2017	2016	2017
May	18.3	18.6	72.6	65.5	26.8	19.3
June	24.5	24.0	62.3	62.0	39.9	36.8
July	27.0	26.5	58.5	55.7	-	17.2
August	27.0	26.6	61.1	54.9	-	-
September	22.5	22.1	60.0	57.6	1.8	11.7
Mean	23.86	23.56	62.9	59.14	-	-
Total	-	-	-	-	68.5	85.0

*Data from the Regional Directorate of Meteorology, Canakkale, Turkey

The traits such as day of tasseling (DT), day of silking (DS), plant height (PH), first ear height (EH), ear length (EL), ear width (EW), number kernel per ear (NKPE), thousand grain weight (TGW), besides quality parameters (yield, protein content, oil content, oleic acid content, linoleic acid content) were investigated.

Grain oil content was determined according to the method TSE-973 EN ISO-659 (Anonymous, 2000). Investigated fatty acids (Oleic acid, linoleic acid and linolenic acid) contents were determined by using the UPAC model Gas -Liquid Chromatography.

Kernel protein content (%) was calculated by multiplying by 6.25 factor, nitrogen percentage obtained by Kejdahl method (Kirk and Sawyer, 1991).

Table 3 - The results of variance analysis investigating agronomical and quality traits (Df: degree of freedom, DT-day of tasseling, DS-day of silking, PH-plant height, EH-first ear height, EL-ear length, EW-ear width, NKPE-number of kernels per ear, PCA-principal component analysis, TGW-thousand grain weight, Rep- replications, *

Source of Variation	Df	DT	DS	PH	EH	EL	EW	NKPE
Rep	**1**	**0.22**	**2.03**	**2085.09***	**1918.96***	**20.29***	**0.12***	**2255.8**
Year	1	153.6*	176.82*	109.41	205.84	4.58	0.15*	3.68
Hybrid	9	92.51*	98.68*	1452.29*	320.82*	9.03*	0.17*	31397.14*
Year×Hybrid	9	26.56*	28.3*	318.9*	167.25*	5.14*	0.09*	5744.85
Error	39	0.95	1.49	99.3	71.16	2.32	0.03	3491.03
Source of Variation	Df	TGW	Yield	Oil	Protein	Oleic	Linoleic	Linolenic
Rep	1	801.02	388.57	0.01	0.01	3.63	4.27	0
Year	1	150.42	12283.42	0.04	0.06	0	0.36	0
Hybrid	9	2729.19*	130157.96*	1.13*	4.56*	98.81*	77.55*	0.1*
Year×Hybrid	9	1217.71	14407.21	0.57*	0.42*	72.5*	61.84*	0.06*
Error	39	759.67	10491.4	0.06	0.18	6.04	6.34	0

Statistical analysis

All obtained data were subjected to analysis of variance using Statistical Analysis System (Bartolome and Gregory, 2000). Differences among genotypes for examined traits were analyzed by the LSD test ($P \leq 0.05$).

PCA-Biplot analysis was used to present the data obtained from the study in a comprehensible way. These analyzes were carried out using the ggp-ubr package in the R package program (R, 2018). In addition, the relationships between the examined properties were examined using Pearson's correlation test.

Results and discussion

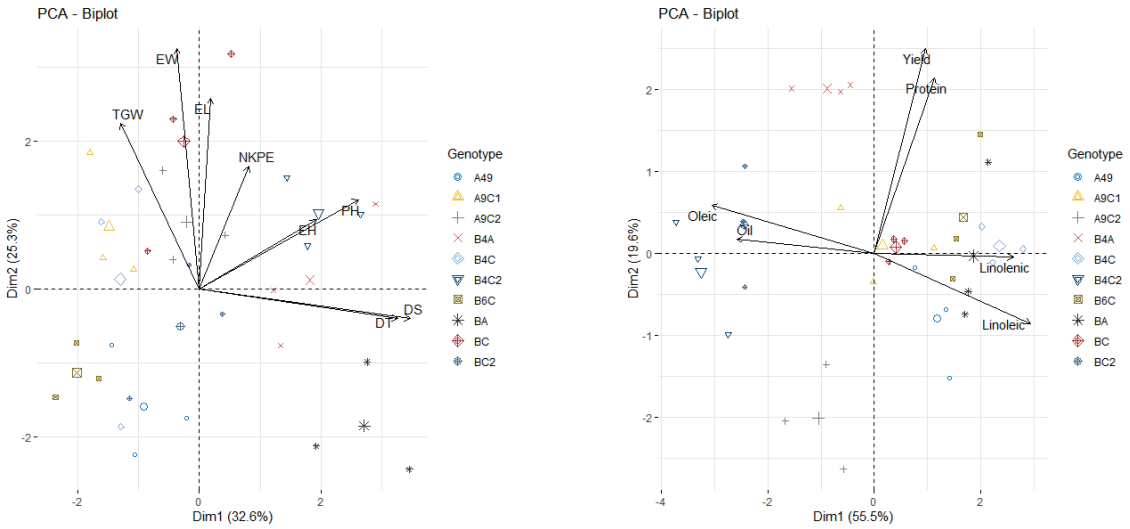
Analysis of Variance

Results of the analysis of variance (as reported in Table 3) showed significant differences for grain yield and other measured traits of hybrids under study. While the year effect was significant for DT, DS and EW, genotype x year interaction effect was significant for almost all agronomical (DT, DS, PH, EH, EL, EW) and quality pa-

Table 4 - Results of correlation analysis for all investigated agronomical and quality traits based on 2-year combined data (Df: degree of freedom, DT-day of tasseling, DS-day of silking, PH-plant height, EH-first ear height, EL-ear length, EW-ear width, NKPE-number of kernels per ear, PCA-principal component analysis, TGW-thousand grain weight, Rep- replications, *

	DT	DS	PH	EH	EL	EW	NKPE	TGW	Yield	Oil	Protein	Oleic	Linoleic
DT													
DS	0.96**												
PH	0.33*	0.36**											
EH	0.06	0.08	0.36**										
EL	-0.08	-0.05	0.30*	0.34**									
EW	0.05	0.03	0.08	0.28*	0.38**								
NKPE	0.10	0.15	0.26*	0.17	0.36**	0.37**							
TGW	-0.11	-0.20	-0.02	-0.06	0.03	0.24	0.06						
Yield	0.07	0.09	-0.02	0.01	-0.04	0.14	0.46***	0.05					
Oil	0.18	0.08	0.05	0.07	-0.10	0.17	-0.02	0.34**	0.15				
Protein	-0.22	-0.19	-0.20	0.23	-0.27*	0.05	-0.02	-0.16	0.28*	-0.01			
Oleic	0.37**	0.32*	0.12	0.24	-0.03	0.28*	0.16	0.32*	0.28*	0.70**	-0.01		
Linoleic	-0.35**	-0.30*	-0.04	-0.25	0.07	-0.25	-0.12	-0.28*	-0.32*	-0.67**	-0.04	-0.99**	
Linolenic	-0.32*	-0.28*	-0.24	-0.22	-0.07	-0.37**	-0.17	-0.38**	-0.14	-0.51**	-0.02	-0.77**	0.71**

Fig. 1 - PCA-Biplot analysis of agronomic traits (left) and grain yield and kernel quality traits (right) based on first experimental year (2016) data. DT-day of tasseling, DS-day of silking, PH-plant height, EH-first ear height, EL-ear length, EW-ear width, NKPE-number of kernels per ear, PCA-principal component analysis, TGW-thousand grain weight



rameters besides yield. These results are in agreement with previous studies (Egesel et. al, 2011; Wassom et. al, 2008) according to which the genetic factors have higher influence on these traits than the environmental factors. These results are also similar to results reported by Kusaksiz and Kusaksiz (2018) who also conducted field trials to evaluate some new maize varieties for two years (2016 and 2017) in Manisa (West of Turkey). They reported that year effect resulted to be significant ($P<0.01$) for number of leaves per plant, stem diameter, ear length and crude protein content in some new maize genotypes.

PCA-Biplot Analysis

PCA-Biplot analysis was carried out on data of both years separately and then on the two-years average data and through the analysis taking into consideration the effects of multiple traits. According to the PCA-Biplot graphics for the first experimental year (2016) data (Figure 1), it can be said that the BC and A9C1 hybrids performed better than other genotypes for TGW, EW and EL features. In addition, it is evident that B4C2 hybrid performed better in terms of PH and EH features, and BA and B4A hybrids performed better than other genotypes for DS and DT features (Figure 1).

Another important issue of this study was to evaluate the usefulness of the GGE-Biplot analysis to compare hybrids in terms of all investigated traits. This method

Fig. 2 - PCA-Biplot analysis of agronomic traits (left) and rain yield and kernel quality traits (right) based on second experimental year (2017) data. DT-day of tasseling, DS-day of silking, PH-plant height, EH-first ear height, EL-ear length, EW-ear width, NKPE-number of kernels per ear, PCA-principal component analysis, TGW-thousand grain weight

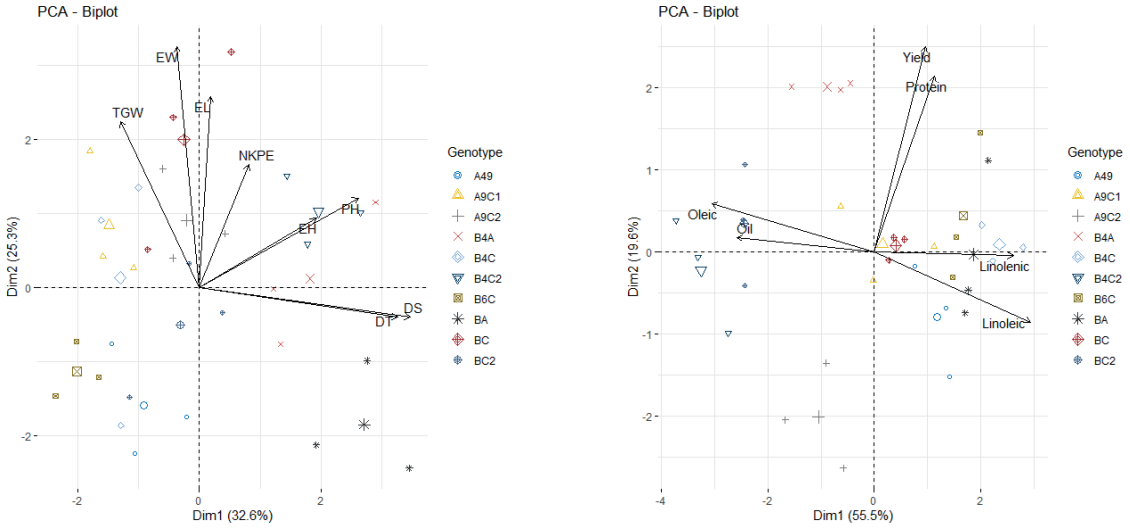
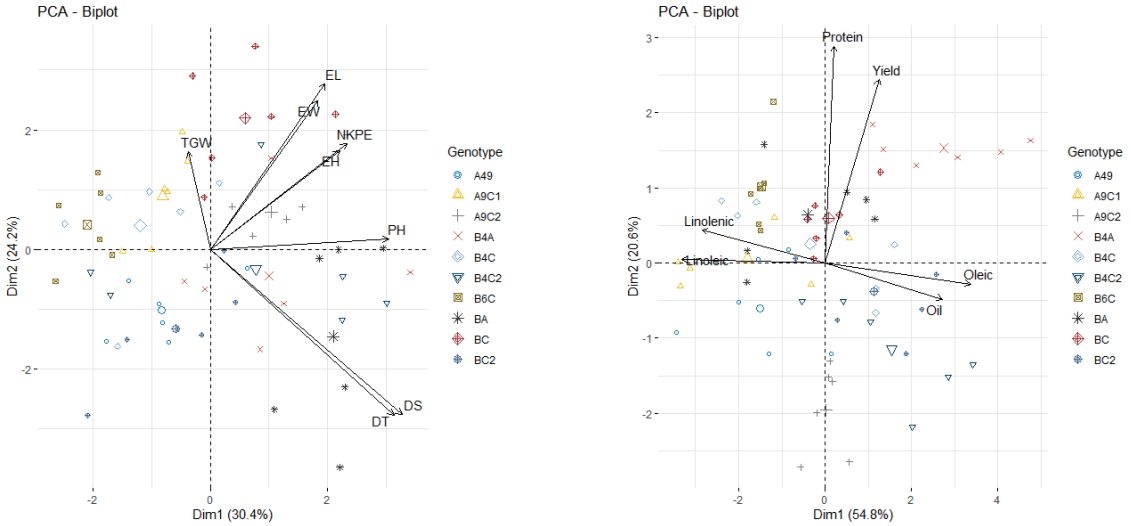


Fig. 3 - PCA-Biplot analysis of agronomic traits (left), grain yield and kernel quality traits (right) based on 2-experimental years (2016 and 2017) data. DT-day of tasseling, DS-day of silking, PH-plant height, EH-first ear height, EL-ear length, EW-ear width, NKPE-number of kernels per ear, PCA-principal component analysis, TGW-thousand grain weight



clearly showed the differences between genotypes and years effect supporting that biplot analysis is more useful than conventional analysis in maize comparison trials (Badu-Apraku et. al, 2013; Kahriman et al, 2016).

According to the graph of the yield and quality characteristics for the second year (2017, Figure 2), while B4A hybrid stood out in terms of yield and protein content , the B4C2 hybrid performed better in terms of oil and oleic acid while BA, B6C, A49, B4C hybrids performed better for linoleic and linolenic acid. Relationships between features shown in PCA-Biplot graphics can be evaluated according to the angles between vectors. The smaller the angle between any two traits, the more closely related they are. According to that it can be observed that from botanical features DS and DT, PH and EH, EL, EW, TGW and NKPE showed positive relationships (Figure 1a). Analysis of yield and quality features showed positive correlations between total oil content and oleic acid, linoleic acid and linolenic acid, and protein content and yield. On the other total oil content and oleic acid were negative correlated with linoleic and linolenic acids (Figure 1b).

The PCA-biplot graphic for second year (2017) agronomical traits shows that the BA hybrid performed better than other hybrids for DS and DT, while the A9C2 and B4A hybrids perform better than other hybrids for PH, NKPE and EW (Figure 2a). Furthermore, BC and B4C2 hybrids had higher values for EL, EH. The BA hybrid performed better than other hybrids for quality features like yield and protein content (Figure 2b), while A49 and B4C2 had advantages in compositional traits such as oleic acid, oil, linoleic and linolenic acid content.

In combined PCA-Biplot graphs for the two experimental years, the BC hybrid showed outstanding values for traits like TGW, EW, NKPE, EH and EL. Furthermore, the BA hybrid resulted better than other hybrids for other yield components like PH, DS and DT (Figure 3a). B4A variety performed better than other hybrids for yield and protein content while the B4C2 hybrid performed better than other hybrids for oil and oleic acids content (Figure 3b).

Relationships among investigated traits

Pearson's correlation analysis results indicating the relationships among the investigated features are presented in Table 4. It is evident that DS and DT properties showed statistically significant relationships with PH, oleic acid, linoleic and linolenic acid (Table 4). Plant height is one of the factors that can affect grain yield (Kun, 1996). The significant variation between varieties in terms of plant height reveals that the varieties react differently to differences between years in environmental conditions. Kusaksiz (2018), also reported year and cultivar x year interaction effects were found to be significant for plant height.

Kökten and Akçura (2017) reported positive and significant correlations between EW, NKPE and TGW. In our study, NKPE had very significant effect on traits like yield and quality. There were positive relationships between NKPE and yield; positive and significant relationship between EL and EW and between DS and DT were observed (Figure 3). Many researchers found that there are positive and significant relationships between NKPE and yield (Gur and Kara, 2019; Sekeroglu et al, 2000; El Shouny et al, 2005; Kokten and Akcura, 2017).

Because the angles between these parameters in our PCA figure (see Figure 3) were smaller than 90°, this also indicated positive correlation between them.

This relationship is confirmed by Pearson's correlation analysis (Table 4). In addition, both Figure 3a. and Table 4. showed that there was positive correlation (r = 0,36**) and close relationship between EH and PH.

All of the graphs showed that the oleic acid content (Figure 1b, 2b and 3b) had negative association with the other fatty acids and this relationship was also supported by correlation analysis (Table 4). Our results are in agreement with the results of previous studies (Egesel et al, 2011; Wassom et al, 2008) and can be explained by the fact that linoleic and linolenic acids are biosynthesized from oleic acid (Egesel et al, 2011).

Conclusions

The results of this study showed that the tested maize hybrids had significant differences in terms of their vegetative and grain quality characteristics.

Among the cultivars tested, B4A, BC genotypes provided evidence of superior performance in terms of both yield and grain quality characteristics tested.

Acknowledgements

Many thanks to Dr. Fatih Kahriman for the statistical and graphical analysis and also thanks to Dr. Mariann Rakszegi for the contributions and to Dr. Paola Tosi for critically reading and editing of the manuscript. This work is also based upon the work from COST Action 18101 SOURDOMICS – Sourdough biotechnology network towards novel, healthier and sustainable food and bioprocesses, supported by COST (European Cooperation in Science and Technology), where the author is the Dissemination and Communication Coordinator. COST is a funding agency for research and innovation networks.

Conflicts of Interest: The author declares no conflict of interest.

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